IGS 09-03

WO 09-687855-0

P.O. 10-458808

WO

eq. # 2TGX-402

IP7019323

LP

LSB

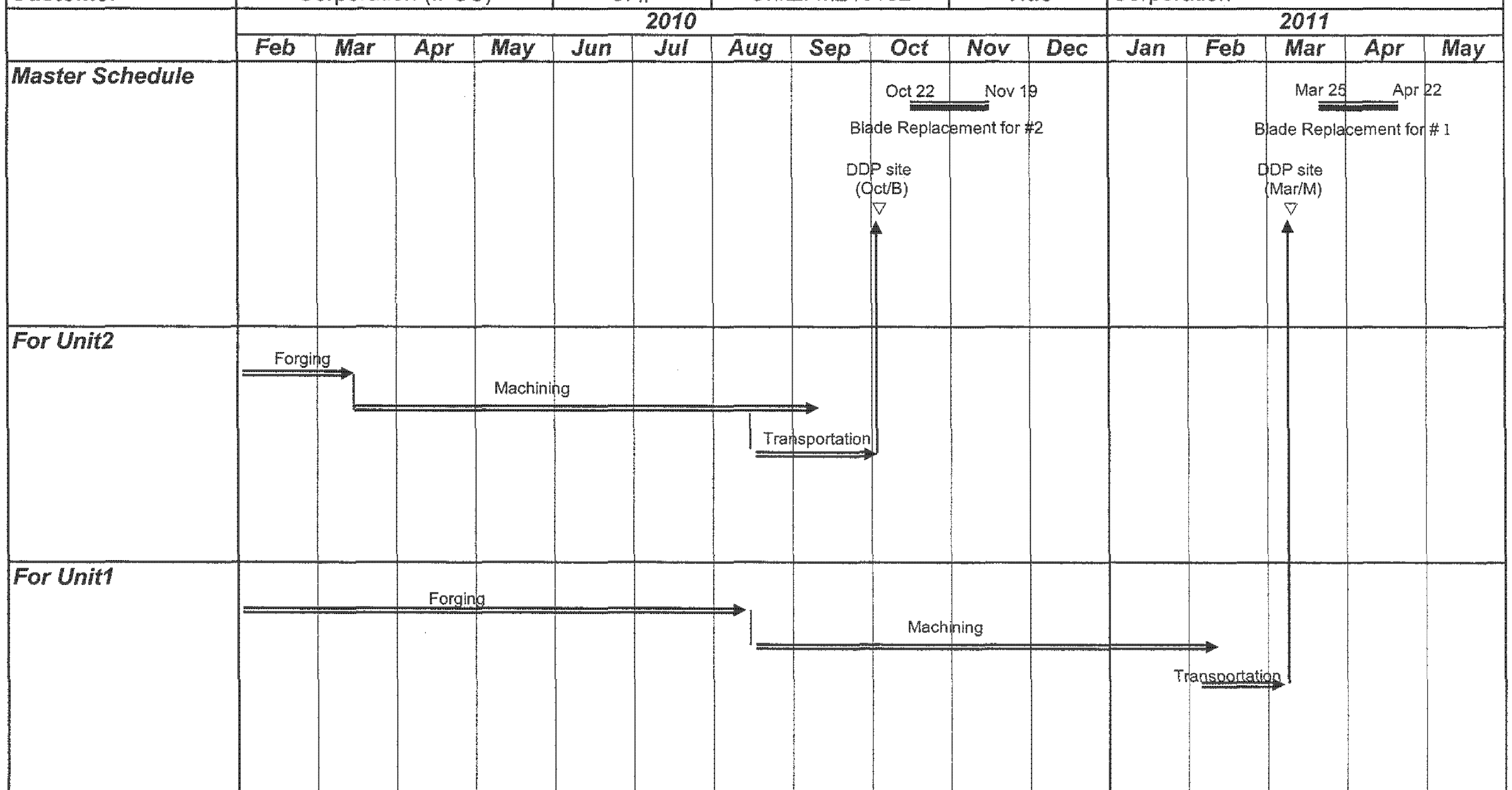
Replacement

08—

7019324

Engineering Schedule

Customer	Intermountain Power Service Corporation (IPSC)	**O/#**	Unit1: M246150 Unit2: M246152	**Title**	Manufacturing Schedule for LSB Replacement for Intermountain Power Corporation



	Thermal & Hydro Power Systems & Services Div. Thermal Power Services Engineering Dept. Global Plant Mechanical Engineering Group	Approved by	Checked by	Prepared by
		ISSUED SEPT. 22		

IP7019325

INTERMOUNTAIN POWER SERVICE CORPORATION

December 8, 2009

Mr. Chris Bernard, Director, STG Retrofits
Toshiba International Corporation - Power Systems Division
6 Dickinson Drive, Bldg 300, STE 2
Chadds Ford, PA 19317

Re: Revised Letter of Intent to Award Contract 10-45808
LP Turbine Last Stage Bucket Replacement

Dear Mr. Bernard:

Intermountain Power Service Corporation (IPSC) hereby agrees to purchase and directs Toshiba International Corporation (TIC) to commence work on the two unit package of LP Turbine Last Stage Buckets as identified in TIC's proposal No. SPS-GMI-GNRL-0117, dated September 14, 2009, subject to the terms described in this Letter of Commitment Agreement (LOC Agreement).

The terms and conditions of this LOC agreement in order of precedence are:

1. Those described hereunder.
2. TIC's proposal No. SPS-GMI-GNRL-0117, dated September 14, 2009.
3. The Terms and Conditions contained in Section 1 of the Proposal as may be modified by mutual agreement between IPSC and TIC.

All terms combined constitute the LOC Agreement and this LOC Agreement shall remain in full force and effect until such time the parties' have executed a formal Contract, which shall supersede this LOC Agreement. Target date for completion of such document is January 15, 2010. If a formal Contract is not executed on or before February 15, 2010, IPSC will pay TIC Termination Charges according to the Cancellation Schedule contained on Page 4 of the Commercial Section of the Proposal unless this LOC Agreement is extended by mutual agreement.

IPSC agrees to make payments per the Payment Schedule, Section 2.4 on Page 3 of the Commercial Section of the Proposal.

The date of the parties' agreement for purposes of the Payment and Termination Schedules shall be December 1, 2009.

Acknowledge your acceptance of this LOC Agreement by signing below and returning the signed document.

Jon P Christensen FOR GWC — DEC 8, 2009

George W. Cross — Date
President and Chief Operations Officer

TIC Authorized Representative — Date

JKH:jmj

December 8, 2009

R1

Mr. Chris Bernard, Director, STG Retrofits
Toshiba International Corporation - Power Systems Division
6 Dickinson Drive, Bldg 300, STE 2
Chadds Ford, PA 19317

Revised Letter of Intent to Award Contract 10-45808
LP Turbine Last Stage Bucket Replacement

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Acknowledge your acceptance of this LOC Agreement by signing below and returning the signed document.

George W. Cross President and Chief Operations Officer	Date
TIC Authorized Representative	Date

JKH:

IP7019327

IGS09-03 LP Turbine Last Stage Bucket Replacement Proposals Evaluation

	Toshiba	MDA	TurboCare	GE (a)	GE (b)
				Based on GE's initial proposal	
Quoted Price	**9,994,000**	11,506,504	14,196,553	14,504,000	14,998,000
difference	-	1,512,504	4,202,553	4,510,000	5,004,000
Evaluated Price[1] (+stuck pins)	**10,073,000**	11,585,504	14,196,553	14,504,000	14,998,000
difference	-	1,512,504	4,123,553	4,431,000	4,925,000
Evaluated Price[2] (+additonal studies)	**10,073,000**	11,585,504	14,196,553	13,954,000	13,547,600
difference		1,512,504	4,123,553	3,881,000	3,474,600
Evaluated Price[3] (+contengencies)	**11,043,843**	13,549,654	16,271,673	16,183,930	15,777,530
difference	-	2,505,811	5,227,830	5,140,087	4,733,687
Pricing Breakdown:					
Replacement Buckets	6,878,000	7,500,000	9,120,000	11,380,000	11,380,000
difference	-		2,242,000	4,502,000	4,502,000
Installation	2,704,000	3,626,488	4,487,107	2,612,000	3,106,000
difference	92,000		1,875,107	-	494,000
Rotor NDT	373,000	380,016	538,146	382,000	
difference	-	7,016	165,146	9,000	
Spare LSB's	39,000	not offered	51,300	65,000	
[1] Stuck pin removal costs					
5% (79/unit)	79,000	79,000		-	-
10% (158/unit)	158,000	158,000		94,800	-
15% (238/unit)	238,000	238,000		189,600	-
>15% (destructive removal)	513,760			494,000	-
[2] Eng Study for Increased Steam Flow (not required)	na	na	na	550,000	550,000
Schedule	28 days	30 days	30 days	30 days	30 days
Penalty	$2,000/hr >30days	$10,000/hr >32 days	$10,000/hr >32 days	$10,000/hr >32 days	$10,000/hr >32 days
maximium penalty	35.2 days 499,700	35 days 1,450,400	35 days 1,450,400	35 days 1,450,400	35 days 1,450,400
Bonus	$2,000/hr <26 days	$10,000/hr <28 days	$10,000/hr <28 days	$10,000/hr <28 days	$10,000/hr <28 days
[3] maximum bonus contingency funds	20.8 days 499,700	25 days 1,450,400	25 days 1,450,400	25 days 1,450,400	25 days 1,450,400
[4] sales tax on materials contingency funds	6.85% 471,143	6.85% 513,750	6.85% 624,720	6.85% 779,530	6.85% 779,530
Rotor Torsional Frequency Analysis	included in quote	included in quote	included in quote	included in quote	included in quote

IP7019328

IGS09-03 LP Turbine Last Stage Bucket Replacement Proposals Evaluation

Bucket Design	Toshiba upgraded GE design (CC with loose covers and sleeves)	Hitachi CCB integral cover & tie-boss	GE redesign tuned to avoid resonance freq at tip area	Original Jethete design with EBW shields added	Original Jethete design with EBW shields added
Installed Rows (30" LSB)	85			>200	
Retrofit Rows (30" LSB USA only)	16			48	
Manufacture Location	Toshiba GE Turbine Components - Japan	Hitachi - Japan	TurboCare - USA	Toshiba GE Turbine Components - Japan	
Forging Location	Wixi Turbine Blade Co. - China or Canton - USA	Japan	USA	USA	USA

	Toshiba	MDA	TurboCare	GE (a)	GE (b)
Installation	ReGenco	MDA		GE	GE
Pin Removal -	3 Hilti shots/pin included, drilling extra, milling removal available	Hilti shots on 15% of pins (238 pins/unit) included, drilling extra		5% stuck pin removal (79 pins/unit) included	cut all buckets, mill out dovetails
Payment Schedule contract execution bucket shipment bkts received on-site completion of install	 15% 60% 20% 5%				

(1) Evaluated Price is the quoted price adjusted for 30 day installation bonus/penalties, 5% stuck pin removal, and engineering studies not requested in the specifications.

Toshiba referrences:
Kelly Stemmler, Machinery Services Fleet Engr, 610-657-1703, Montour U1 LP retrofits, 4 rows 30" LSB's on GE G3, 2008.
Randall Moyer, Station Planner & Turbine Engr, 717-266-7583, Brunner Island U3 LP retrofits, 4 rows 30" LSB's on GE G3, 2006.

GE options:
a. new ebw shielded buckets, old buckets removed by driving all pins out.
b. new ebw shielded buckets, destructive removal of old buckets by cutting and milling.

Dave Spence - Requested Information from Toshiba regarding Intermountain LSB Proposal

From: "Chris Bernard" <chrisb@toshibatic-pa.com>
To: "Dave Spence" <DAVE-S@ipsc.com>
Date: 10/19/2009 9:47 PM
Subject: Requested Information from Toshiba regarding Intermountain LSB Proposal
CC: "Chris Bernard" <chrisb@toshibatic-pa.com>

Dave,

As final follow-up to your recent request:

Item 2. As mentioned in previous transmittal when addressing Item 3 - It is my understanding that our material specifications are at least equal to and in most cases better than those of GE. I haven't personally compared specifications such as forging material as it is not allowed according to the joint venture agreement. The blade material vendor tabulation I sent to you earlier is correct and utilized for both Toshiba and GE blading materials. Forgings are procured from noted vendors that have meet our strict QA/QC standards of which Toshiba has had NO quality issues with – including Wixi in China. It has been confirmed that GE is buying blade forgings from this Chinese company so I don't know of which Chinese vendor they are speaking about. Perhaps they're having material quality issues at Turbine Blading and Preferred?

In light of their accusations, I find it quite interesting that GE continues to procure LSB's from the joint venture in Yokohama. FYI – Toshiba supplies all components (power turbine, steam turbine and generator) for GE "Frame H" combustion turbines except the hot gas path that is manufactured in Greenville, SC. I would say that speaks highly of the quality and reliability of our steam turbines and generators. Quite frankly, it speaks highly of GE's regard for our TG products.

Please be informed the VP Services and I would be pleased to travel this week to meet with your station and executive management to further discuss our capabilities and this project in detail. For that matter we'd be glad to meet with you all and GE to dispel these rumors.

I trust that you had a good hunt and look forward to hearing about it. I will call you sometime tomorrow.

Regards,

Chris Bernard
Director - STG Retrofits

TOSHIBA INTERNATIONAL CORPORATION
Power Systems Division
6 DICKINSON DRIVE, BLDG 300, STE 2
CHADDS FORD, PA 19317
M: 804-334-5094
chrisb@toshibatic-pa.com

From: Chris Bernard
Sent: Friday, October 16, 2009 5:08 PM
To: 'Dave Spence'

Cc: Chris Bernard
Subject: Requested Information from Toshiba regarding Intermountain LSB Proposal

Dave,

Continuation of follow-up to your earlier request:

Item 1. Please find attached file [Reference list for Intermountain.pdf] for ReGENco steam turbine blade and/or replacement services contacts. I understand that none of these projects are similar in scope to Intermountain but, trust that these contacts will provide you with the comfort that ReGENco will provide excellent blading services under Toshiba direction.

The proposed schedule and staffing has been thoroughly reviewed by our experienced lead bladers in Japan. Our scheduling of 28 days includes a full 2 day risk contingency. Coupled with the 2 day grace period, this should allow for ample time to perform this work even if trouble is encountered with removing the blade attachment finger pins.

TIC has currently priced the following staffing for these projects:
TIC (US) site management – 1 day shift + 1 night shift
TSB (Japan) blade specialist – 1 per day
ReGENco field service supervisor (Experienced bladers who frequently work in the field and have done this type project work before) – 1 day shift + 1 night shift.
ReGENco blade technicians – Up to 8 per each day & night shift (The ReGENco blade technicians are or will be trained and qualified according to TSB procedures prior to arriving at site).

After contract award, we would be pleased to work with Intermountain on finalizing the work schedule and emergency contingency plan(s) once all work details are fully understood. I'm a firm believer in planning the work ahead of time then working the plan.

I trust that this completes Item 1 to your satisfaction. Please do not hesitate to contact me with any questions/concerns.

Regards,

Chris Bernard
Director - STG Retrofits

TOSHIBA INTERNATIONAL CORPORATION
Power Systems Division
6 DICKINSON DRIVE, BLDG 300, STE 2
CHADDS FORD, PA 19317
M: 804-334-5094
chrisb@toshibatic-pa.com

From: Chris Bernard
Sent: Friday, October 16, 2009 4:03 PM
To: 'Dave Spence'
Cc: Chris Bernard
Subject: Requested Information from Toshiba regarding Intermountain LSB Proposal

Dave,

Thank you for returning my call this afternoon.

Confirming our telecom this afternoon and as further follow-up to your earlier request:

Item 3. TGTC (Toshiba GE Turbine Component) joint venture is a separate company located in Yokohama, Japan of which Toshiba is the majority owner. In the manufacturing of LSB's - Our companies utilize the same facility, manufacturing processes (including Toshiba's EBW stellite shield attachment process), personnel, QA/QC, procurement and supply vendors. It is my understanding that the only differences are that we each have our own and separate LSB aero designs, material specifications and material inventories. It is also my understanding that our material specifications are at least equal to and in most cases better than those of GE. I haven't personally compared specifications such as forging material as it is not allowed according to the joint venture agreement. I assume the processes are similar at the GE owned facilities of Preferred and Turbine Blading.

I have included the attached file [Blade manufacturing process.pdf] that pictorially describes the manufacturing process. This is the same information that Norm presented at the 10/1 meeting.

Item 4. The NN30 LSB that Toshiba has proposed to supply for the Intermountain project is a design that has been in service since 1978. Though this is an older blade design - It is still efficient by today's standards, well dampened and very reliable. Toshiba has never experienced a single failure of this LSB.

This design has been used for 3600 rpm applications in 25 units and 85 rows of the identical blades.

I have included the attached file [Toshiba NN30 reference.pdf] that includes our 30" LSB reference list, Accumulated experience of the 30" LSB, Similar Japanese "S2" unit to Intermountain and the Joint venture blade manufacturing facility.

I trust that this email addresses items 3 and 4 to your satisfaction.

I should have the ReGENco contact information to you shortly which should complete item 1 and hope to have Tokyo's reply to you by Monday regarding item 2.

Please do not hesitate to contact me with any question/concerns.

Toshiba very much wants to work with you and the Intermountain team. I would be glad to travel to Intermountain to further discuss our capabilities and address any concerns with your management team if you feel it would benefit our cause.

Thank you.

Have a safe and successful hunt!

Regards,

Chris Bernard
Director - STG Retrofits

TOSHIBA INTERNATIONAL CORPORATION
Power Systems Division
6 DICKINSON DRIVE, BLDG 300, STE 2
CHADDS FORD, PA 19317
M: 804-334-5094
chrisb@toshibatic-pa.com

From: Chris Bernard
Sent: Thursday, October 15, 2009 5:23 PM
To: Dave Spence
Cc: Chris Bernard
Subject: Requested Information from Toshiba regarding Intermountain LSB Proposal

Dave,

As further follow-up to Item 1 of your request, please find attached files for Toshiba new equipment:
> Plant locations map and McCoy reports [New STG Reference (Oct2009).pdf]
> Plant coverage listing [TIC Plant Coverage (Oct2009).pdf

Toshiba has been the Number One supplier of new STG equipment for the last six years. TIC was established as a USA corporation in 1967 at the request of our first US customer – PG&E for the Geyser geothermal units. These units, now owned by Calpine, operate under very severe/corrosive steam conditions and I believe are the closest of our units to Intermountain being located in Middletown, CA. I can get you the customer contact information if you are interested in speaking with them or any of our other customers for that matter.

The other information you have requested is forthcoming.

Thank you!

Chris Bernard
Director - STG Retrofits

TOSHIBA INTERNATIONAL CORPORATION
Power Systems Division
6 DICKINSON DRIVE, BLDG 300, STE 2
CHADDS FORD, PA 19317
M: 804-334-5094
chrisb@toshibatic-pa.com

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From: Chris Bernard
Sent: Thursday, October 15, 2009 3:10 PM
To: Dave Spence
Cc: Chris Bernard
Subject: Requested Information from Toshiba regarding Intermountain LSB Proposal

Dave,

As requested (Item 1), please find attached files for Toshiba Other OEM steam turbine retrofit contacts. I have also included a power point slide with Toshiba summary of steam turbine retrofits and generator stator rewind &

rotor replacements for GE equipment.

As you may know, Toshiba has been retrofitting GE equipment since the early 1980s. Because of Toshiba's new STG success in the US and favorable market study results, we officially launched the Other OEM steam turbine retrofit business in 2005 followed by stator rewinds in 2008. We also became majority owner of ReGENco in spring 2008.

The other information you have requested is forthcoming.

Thank you!

Chris Bernard
Director - STG Retrofits

TOSHIBA INTERNATIONAL CORPORATION
Power Systems Division
6 DICKINSON DRIVE, BLDG 300, STE 2
CHADDS FORD, PA 19317
M: 804-334-5094
chrisb@toshibatic-pa.com

From: Dave Spence [mailto:DAVE-S@ipsc.com]
Sent: Wednesday, October 14, 2009 4:49 PM
To: Chris Bernard
Subject: Information Request for Intermountain LSB Proposal

Chris,

Sorry to bother you again, but it's crunch-time on this LSB replacement proposal and I really need some more information from Toshiba/ReGenco to complete our evaluation. I am listing it in this email so we will both know what is needed at this time.

1. References - Can you provide a list of Toshiba steam turbines installed in the US and Canada? I know that Toshiba is just getting into the retrofit market in the US, but are there any domestic retrofit projects that I can get contact info on? We also need ReGenco references.

2. Bucket material specifications - I know that Noriaki covered this in the Toshiba presentation a couple of weeks ago, but I am really getting hit hard from one of your competitors on this. (I won't mention any names, but their initials are GE). They are claiming that your (Toshiba's) forgings for LSB's are inferior to theirs. That's why I have been asking about where the Toshiba buckets are forged? GE is claiming that none of the foundries in China were able to meet their specifications. Yet in the Toshiba presentation, Noriaki indicated that Toshiba's material specs are tighter than GE's. Can you get me any more information/documents on this topic?

3. LSB manufacturing details - I need to know what specific manufacturing processes are conducted at the joint venture Toshiba/GE blade manufacturing facility in Japan. Once again GE is blowing a lot of smoke about how and where their buckets are manufactured. I know that the stellite shield EBW attachment process is the same, but are there any other similar manufacturing processes?

4. Reliability of the Toshiba NN30 blade - How long has this specific design been in service? How many rows installed worldwide in 3600 rpm application? What about operating history? Has there been any failures on this design?

You know Chris, that I wouldn't be asking these specific questions if Toshiba wasn't on the short list, so I would appreciate your timely consideration on these inquiries.

Thanks for your help,

DS

David Spence, P.E.
Lead Engineer - IPSC Technical Services
Intermountain Generating Station
(435) 864-6449
dave-s@ipsc.com

LP Turbine LSB replacement proposal evaluations

	Toshiba	MDA	TurboCare	GE (a)	GE (b)	GE (c)	GE (d)
Total Price	9,994,000	11,506,504	14,196,553	14,504,000	14,998,000	12,701,000	12,995,000
Replacement Buckets	6,878,000	NA	9,120,000	11,380,000	11,380,000		
Installation	2,704,000	NA	4,487,107	2,612,000	3,106,000		
Rotor NDT	373,000	380,016	538,146	382,000			
Spare LSB's	39,000	not offered	51,300	65,000			
Schedule	30 days	32 days	32 days	32 days			
Bucket Design	GE improved	Hitachi CCB	GE improved	Original shielded			
Bucket Manufacturer/Location	Toshiba/Japan	Hitachi/Japan	TurboCare/USA NC & CN	Japan (toshiba)	Japan (toshiba)	refurb UK	refurb UK
Installation	ReGenco	MDA	TurboCare	GE			
Penalty	$2,000/hr >30days	$10,000/hr >32 days					
Bonus	yes	yes	yes				
Pin Removal	max 3 Hilti shots/pin drilling extra	Hilti shots on <15% of pins included		<5% stuck pins	cut all bkts out	<5% stuck pins	<5% stuck pins U2 cut all U1 bkts out
Payment Schedule							
contract execution	15%						
bucket shipment	60%						
bkts received on-site	20%						
completion of install	5%						

GE options
a. new ebw driving all pins out
b. new ebw cut out old bkts
c. new ebw U2, refurb U1driving all pins out
d. new ebw U2, refurb U1 cut out U1 bkts

IP7019336

MAINTENANCE SCHEDULE FOR INTERMOUNTAIN POWER PROJECT
SPRING 2010

FY	YEAR	FACILITY	UNIT	START DATE	END DATE	DURATION IN DAYS	MAINTENANCE SCHEDULE
10-11	2010	IGS	2 (Note 3)	23-Oct	6-Dec	44	MAJOR See note 4
	2011	IGS	1(Note 3)	12-Mar	25-Apr	44	MAJOR
	2010	STS	BIPOLE	24-Nov	28-Nov	5	STS Upgrade

NOTES:
1. IGS START DATES ARE SHOWN AS SATURDAYS, BUT ACTUAL UNIT SHUTDOWN WILL USUALLY OCCUR AFTER PEAK ON FRIDAY EVENING.
2. IGS END DATES ARE MONDAY. UNITS TO BE AVAILABLE FOR FULL LOAD ON END DATE AT 07:00
3. IPSC HAS REQUESTED A SIX WEEK OUTAGE FOR UNIT 2 GENERATOR REWIND AND LAST STAGE TURBINE BLADE WORK. THE OUTAGE WILL OCCUR IN FALL 2010.
4. SINCE UNIT 2 WILL HAVE HAD THE LONG OUTAGE IN FALL 2010, WE DO NOT ANTICIPATE TAKING A SHORT UNIT 2 OUTAGE IN SPRING 2011.

PROJECTED MAINTENANCE SCHEDULE FOR INTERMOUNTAIN GENERATING STATION
SPRING 2010 THROUGH SPRING 2013

FY	YEAR	FACILITY	UNIT	START DATE	END DATE	DURATION IN DAYS	MAINTENANCE SCHEDULED
11-12	2012	IGS	1	8-Mar	17-Mar	9	INSPECTION
	2012	IGS	2	31-Mar	30-Apr	30	MAJOR
12-13	2013	IGS	2	9-Mar	18-Mar	9	INSPECTION
	2013	IGS	1	30-Mar	29-Apr	30	MAJOR
13-14	2014	IGS	1	9-Mar	18-Mar	9	INSPECTION
	2014	IGS	2	29-Mar	28-Apr	30	MAJOR

INTERMOUNTAIN POWER SERVICE CORPORATION

☒ REQUISITION FOR CAPITAL EQUIPMENT

☐ PURCHASE AUTHORIZATION FOR EXPENSE ITEMS

Purpose of Materials, Supplies or Services:

Replacement LP turbine last stage buckets and installation

Date:	
Req./PA No:	248375
P.O. No:	
Vendor:	
Terms:	
FOB:	
Ship Via:	
Conf. To:	

Suggested Vendor: Competitive Bid

Account No. 00-1TGX-402
Work Order No. 09-68785-0
Project No. IGS-09-03

Qty	Unit	Noun / Description Adjective / Catalog # / Seller or Manufacturer	Unit Cost	Extension
1	1	Unit 2 replacement LP turbine last stage buckets and installation for Spring 2010 outage.		$6,035,000.00
[illegible]	1	Unit 1 replacement LP turbine last stage buckets and installation for Spring 2011 outage.		$6,035,000.00
		TOTAL ESTIMATED COST		$12,070,000.00

Remarks:

Delivery requested by [Date] 04-27-10 Originator Spence

Dept. Mgr/Supt. Date Station Manager Date Operating Agent Date

File: 01.03.01

August 6, 2008

Mr. Nick C. Kezman
Operating Agent for IPP
Los Angeles Department of Water and Power
111 North Hope Street, Room 1255
PO Box 51111
Los Angeles, CA 90012

Dear Mr. Kezman:

IGS LP TURBINE LAST STAGE BUCKET REPLACEMENT

Due to observed steam turbine bucket leading edge erosion and the potential for bucket tip failure, we recommend replacing the low pressure turbine L-0 or LSB (last stage buckets) on both of the Intermountain Generating Station Units during the Unit 2, 2010 and Unit 1, 2011 major overhauls. This recommendation is based on reliability concerns stemming from the observed LSB leading edge erosion, bucket design, and material concerns. The service life of these buckets will be exceeded during the next LP turbine outage interval (20-30 yrs operating time). Avoiding repair costs and associated forced outages due to LSB tip failure justifies replacing these buckets during the next scheduled LP overhauls.

Replacing the LSB's on each unit during the next major LP turbine overhauls will require budgeting $6 million per unit for materials and installation. A total outage length of six weeks will be required to complete this work in each outage if all three LP turbine sections (six rows of buckets) are replaced. In order for this work to commence in the Spring 2010 Unit 2 outage a contract would have to be awarded before the end of this year (2008) with funds made available early in 2009.

The last stage buckets installed in the Intermountain Generating Station LP turbines are GE 30" self shielded LSB's. These buckets are made entirely with hardened Jethete base material without stellite erosion shields. GE started installing these buckets in the early 80's to reduce manufacturing costs. Unfortunately the hardening process on this material reduces ductility and increases the tendency for crack propagation.

During the last LP turbine overhauls in 1999 and 2000, the LSB's were dressed to remove high spots in the leading edge erosion area. This was a preventive measure to remove stress risers where cracks could initiate. Since then, the leading edges have eroded further into the base material. The erosion rate on this type of bucket is rapid initially until the surface roughens enough to hold a layer of water which acts as a buffer to reduce further erosion. After this point

IP7019339

the erosion rate drops off. This additional (since 2000) erosion is getting deep enough to effect the integrity of the bucket tip. There is also evidence from finite element analyses conducted on these types of buckets that there is a 7X resonance node near the tip and close to the leading edge which will stimulate crack propagation from surface erosion pitting.

In 2004 several plants experienced failures of GE 33" and 30" self shielded last stage buckets due to high cycle fatigue cracks starting in the leading edge areas near the tip. These failures and the ensuing EPRI reporting prompted GE to issue TIL 1521-2 to address this problem. TIL 1521-2 states that 5 tip loss failures have been identified out of a total of 700 installed rows of self shielded LSB's. The mean time to failure of these 5 incidents was approximately 20 years. The average age of the fleet using these buckets at the time of the report was probably 20 years or less. The longest any of these buckets have been in-service is less than 30 years. Bucket service life is not solely time based, but is a function of operating conditions such as; severe cyclic duty, low steam quality, high back pressure, and repeated torsional events. Based upon the observed erosion and the factors listed above, there is a high probability that there will be a LSB tip failure or failures during the next 10 years of operation.

Last Spring following the Unit 1 outage, GE recommended replacing the L-0 buckets in all three LP turbines during the next major outage (attachment p1). This recommendation was based on the extent of leading edge erosion observed during the outage inspections and the leading edge grooming of these buckets in the 1999 outage.

During the U2 Spring 2008 outage GE brought in a steam path specialist to inspect the LSB's and measure chord lengths in the tip area to determine the extent of the erosion. These measurements were reviewed by GE steam path engineers in Schenectady. Their report states that our LSB erosion is trending similar to buckets of the same age, although GE could not find other erosion measurements that were comparable to ours. GE provided plots comparing our LSB erosion to the erosion on 33.5" LSB's that have failed (attachment p2-4). These plots show that our erosion is higher, but GE states that we can't draw any conclusions on life expectancy from this comparison because of the differences between 30" and 33.5" buckets.

After review of the Unit 2 inspection and measurements, GE is still recommending L-0 row replacements during the next suitable outage to mitigate risks. They stated that our LSB's are acceptable for further operation, but also recommended that we need to order spare buckets in case replacement is needed in short order (attachment p5).

A consultant from Mechanical Dynamics & Analysis (MD&A) with GE steam path design background was also hired to inspect the Unit 2 LSB's and give us a recommendation on bucket replacement. MD&A recommends replacing these buckets with shielded buckets to minimize the chance of a bucket failure (attachment p6). Neither GE or MD&A would state what the chance or probability of bucket tip failure would be if they are not replaced. MD&A indicated that we would have to be willing to live with the risk of bucket tip failures if we continued to operate with the existing buckets through the next LP outage interval.

A third company, TurboCare has also provided information relevant to the decision to replace our LSB's. After reviewing pictures of Unit 2's LSB leading edge erosion, they provided results of a finite element analysis and resonance node study they have conducted on GE's 30" unshielded LSB's. This study shows that there is a 7X operating speed resonance node close to the leading edge of these buckets (attachment p7-8). Surface erosion in this area initiates cracks that are propagated by the resonance node leading to bucket tip failure. Based on the extent of our erosion and the bucket design, TuboCare states that Intermountain has a very high probability for LP turbine LSB tip failures.

General Electric and several non-oem suppliers offer replacement buckets which can be installed with minimal modifications to the LP turbines. Lead times for manufacturing and scheduling installation are one to two years for most of the suppliers.

Sincerely,

George W. Cross
President and Chief Operations Officer

DCS:
Attachment

BUCKETS

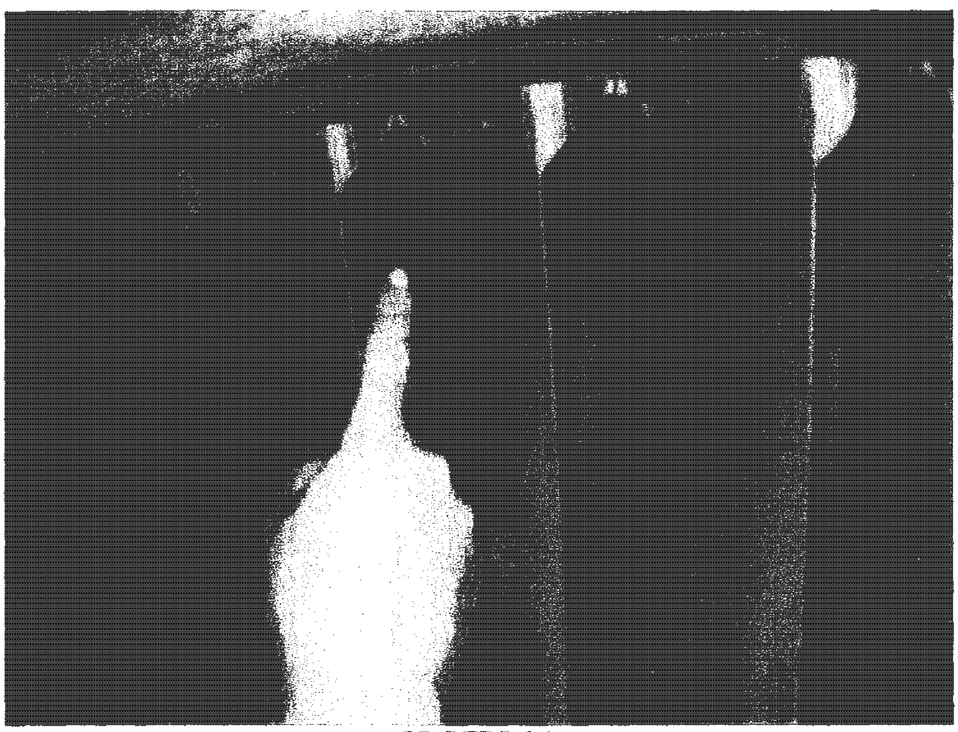
LP Buckets

Assembly; LP A,B and C

The L-0's on LP A, B, and C were visual and NDE examioned per TIL-1521 and GEK46354. As noted in past IPP QC records there is erosion on Inlet Side of all L-0 Buckets.

PRO comments are profile doesn't cause to much short term concern but should be replaced at next major outage.

Monitor LP L-0's per TIL-1521 and GEK46354 and replace on next major outage.



LP C TE L-0 1

IPP, Unit 2 LSB Erosion (270T151)

April 7, 2008

TIL 1521, LSB Erosion

Descriptive Statistical Analysis

	Mean	Standard Deviation	Min.	Max	Median
LPA TE1	0.059	0.033	0.026	0.131	0.049
LPA TE2	0.117	0.011	0.085	0.120	0.120
LPA GE1	0.067	0.020	0.048	0.113	0.060
LPA GE2	0.054	0.015	0.040	0.092	0.050
Averages	0.074				0.070
LPB TE1	0.110	0.011	0.095	0.126	0.110
LPB TE2	0.121	0.021	0.093	0.160	0.126
LPB GE1	0.127	0.017	0.112	0.167	0.121
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Averages	0.115				0.112
LPC TE1	0.117	0.019	0.104	0.162	0.110
LPC TE2	0.113	0.016	0.099	0.146	0.106
LPC GE1	0.142	0.014	0.127	0.166	0.136
LPC GE2	0.134	0.018	0.114	0.165	0.129
Averages	0.126				0.120

Notes:

- Statistical erosion agrees with relative back pressure between hoods, i.e. LPA has highest BP and least statistical erosion while LPC has lowest BP and highest statistical erosion: LPA – 0.062, LPB – 0.115, LPC – 0.126
- Uniform erosion between ends within respective hoods (pg 6).

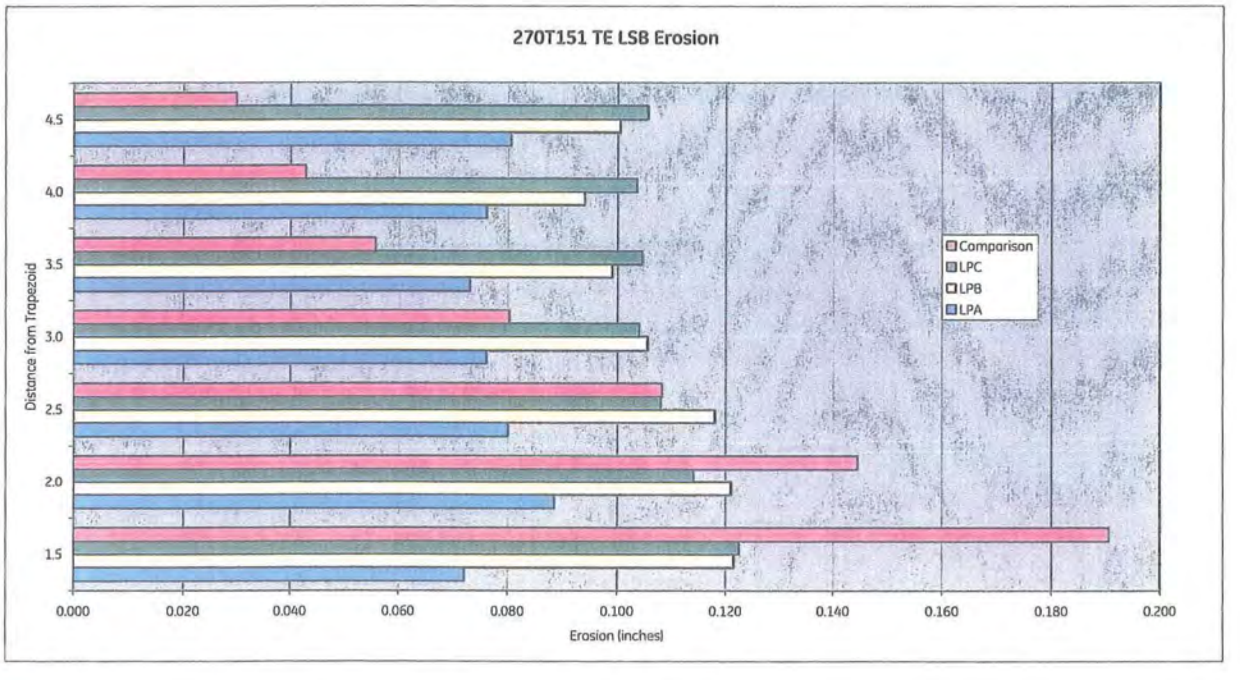
```
Two Sample T-Test and Confidence Interval
Two sample T for Erosion
End          N      Mean     StDev    SE Mean
GE          60    0.1043    0.0375     0.0048
TE          60    0.0981    0.0333     0.0043
95% CI for mu (GE) - mu (TE): ( -0.0066,  0.0191)
T-Test mu (GE) = mu (TE) (vs not =): T = 0.96  P = 0.34  DF = 116
Since P > 0.05 there is no statistically significant difference between sample means
```

- Atypical erosion pattern from tip to approximately 6 inches down from the tip. Greatest erosion occurring at the 1.5 inch and 6 inch measuring points and lesser erosion in between these two points.

IPP, Unit 2 LSB Erosion (270T151)

April 7, 2008

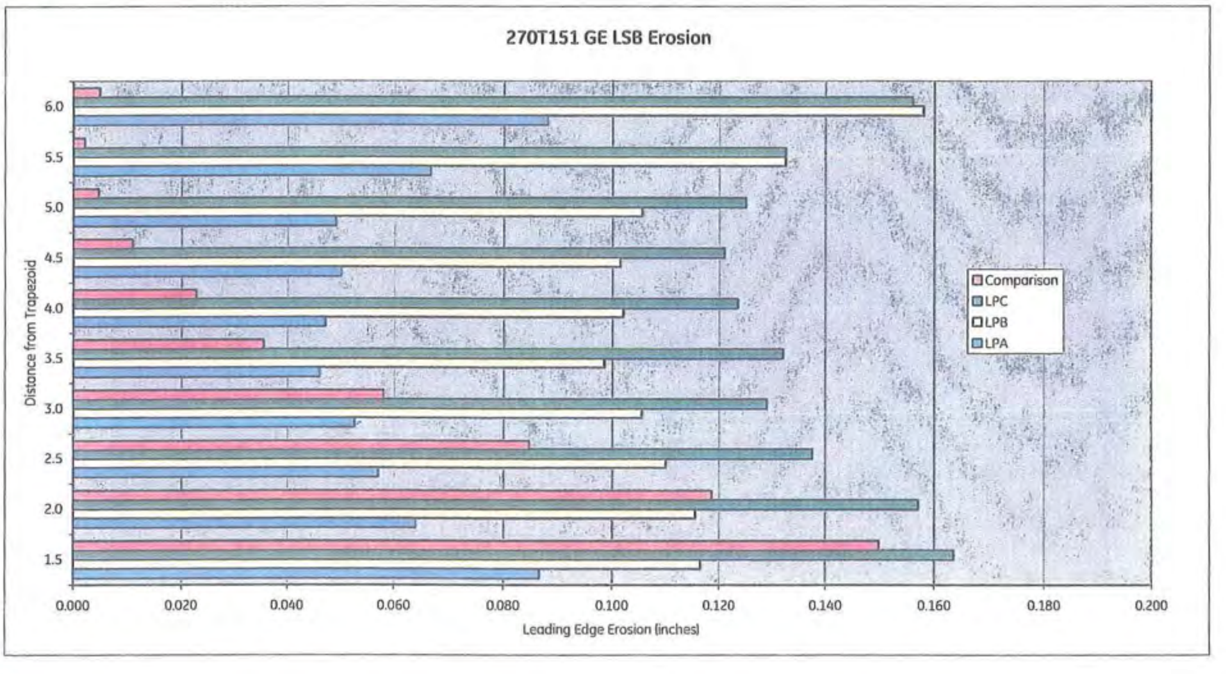
Comparison of IPP's erosion to erosion measured on a 33.5" D8 turbine where LSBs were replaced.



IP7019344

IPP, Unit 2 LSB Erosion (270T151)
April 7, 2008

Comparison of IPP's erosion to erosion measured on a 33.5" D8 turbine where LSBs were replaced (continued)



IP7019345

5/31/08

Dave,

I know you're waiting for this so I'm sending what I have:
<<270T151 LSB Erosion Statistics.ZIP>>
I've held onto this for a few days hoping to find other erosion measurements we could compare yours to, but I haven't found anything comparable. The one 'comparison' data I included here was taken from a Unit that had a LSB failure, but I really need to warn you about making any conclusions using the 'comparison' data. The inherent differences between yours and the 33.5" LSB are enough that we can't draw any correlation between erosion and life expectancy, i.e. the 33.5" LSB is approximately 3.5" longer than yours which gives it a much higher tip speed and the mass geometries at the tips are also different enough that it would differentiate problematic erosion thresholds. So, the 'comparison' erosion in this case is really only good for showing how your erosion is tracking relative to another unit that had an unfortunate LSB failure (i.e. tip liberation).

After John and I measured the Unit 2 LSBs last outage I ran a statistical analysis to confirm the data's reliability and then submitted the data to Schenectady for their review and recommendations. After reviewing the measurements, their conclusions have only subtle differences from the one in the outage report, which should be expected since our first opinion was based on less than optimal photos while the second opinion was based on precision measurements. Upon review of the measurements, Schenectady believes the buckets are trending similar to other buckets of same age, but recommends ordering spare buckets in case a replacement is needed in short order. They also recommend monitoring the buckets including the following:

- Perform mag particle test as convenient
- Visual inspections
- Measure erosion as convenient

These LSBs are acceptable for further operation, but to mitigate risks it is recommended to plan a row replacement during the next suitable outage. In your case - weighing the risks of an aging row of buckets and your LP section outages.

Look this over and let me know what else you may need.

Cecil

Cecil D. James PhD, P.E.
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General Electric Company

RECOMMENDATIONS/CONCLUSIONS

1. The last stage bucket erosion is not sufficient to require replacement if the buckets had erosion shields.

   - The level of erosion on the admission edge near the tip is less than that seen on shielded buckets which have continued to operate successfully. There were no significant notches observed in the leading edge which would produce stress concentrations and increase the possibility of crack initiation. Please note that cracks that do initiate in erosion shields on 30" continuously coupled buckets tend to stop in the ductile Inconel welds that attach the shields.

2. Replacing these unshielded L-0 buckets with shielded buckets would minimize the chance of a bucket failure.

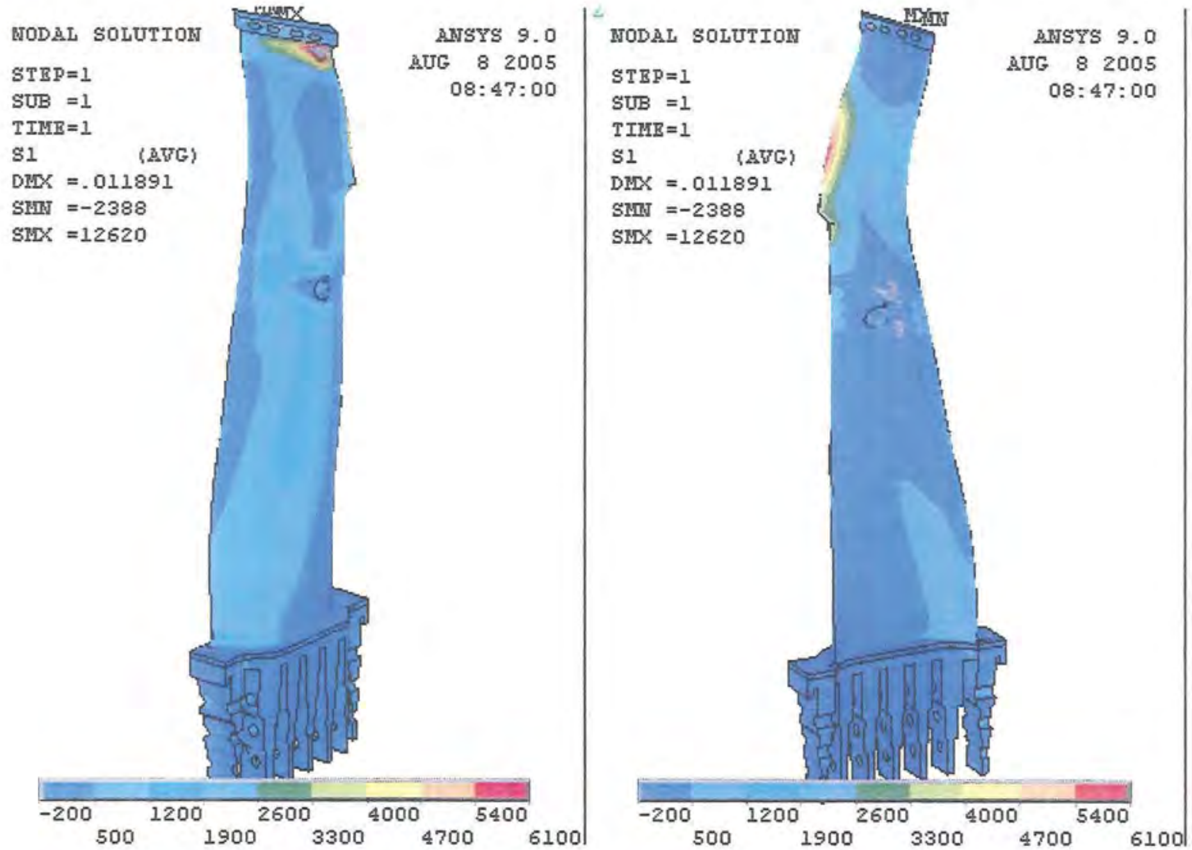
   - Last stage bucket failures in the last few years seem to indicate that unshielded last stage buckets, like the buckets on the Intermountain units, may have a shorter life than shielded buckets. MD&A is aware of 4 tip failures of unshielded 30" last stage buckets in 2004 and 2005 but unaware of similar failures of the older shielded 30" continuously coupled buckets. Unlike the buckets with Stellite erosion shields, the unshielded buckets do not have a ductile Inconel layer to stop cracks that initiate on the leading edge. In addition, it appears that the hardness level of the buckets may have been increased and ductility decreased when the EBW shields were eliminated. The failures all occurred after cracks initiated on the leading edge near the tip and propagated across the blade until the tip broke off, causing a forced outage. There is suspicion that incorrect installation of replacement covers caused 2 of the 30" failures but it is likely that the negative aspects of the unshielded design contributed to the failures. Please note that MD&A inspected one of the 30" rows that had a bucket failure and found the leading edge erosion to be less than that of many 30" and 33 ½" L-0 rows previously seen that are operating reliably.

3. The last stage covers should be replaced if the buckets are not replaced.

   - The erosion of up to nearly 2/3 of the thickness of the discharge side tenons is severe enough to require replacement. Please note that special attention should be given to the swelling of the discharge tenons because incorrect swelling of the discharge tenons is considered the likely cause of two of the 30" L-0 failures. It appeared that extending the swelling too far toward the bucket restricted the ability of the bucket to untwist during service and increased the stress at the base of the trapezoidal section at the tip of the vane. The increased stress plus erosion notches in the leading edges combined to initiate cracks which resulted in tip failures on the unshielded 30" buckets. This special attention to the swelling process should also be applied to a new bucket installation if the new buckets have the same side entry cover design as the current last stage buckets.

4. Don't run with high back pressure.

   - Running with high back pressure increases the vibratory stresses in the buckets, especially during low load operation. Although the continuous coupling of the last stage buckets reduces the response to the stimulus from high back pressure, the



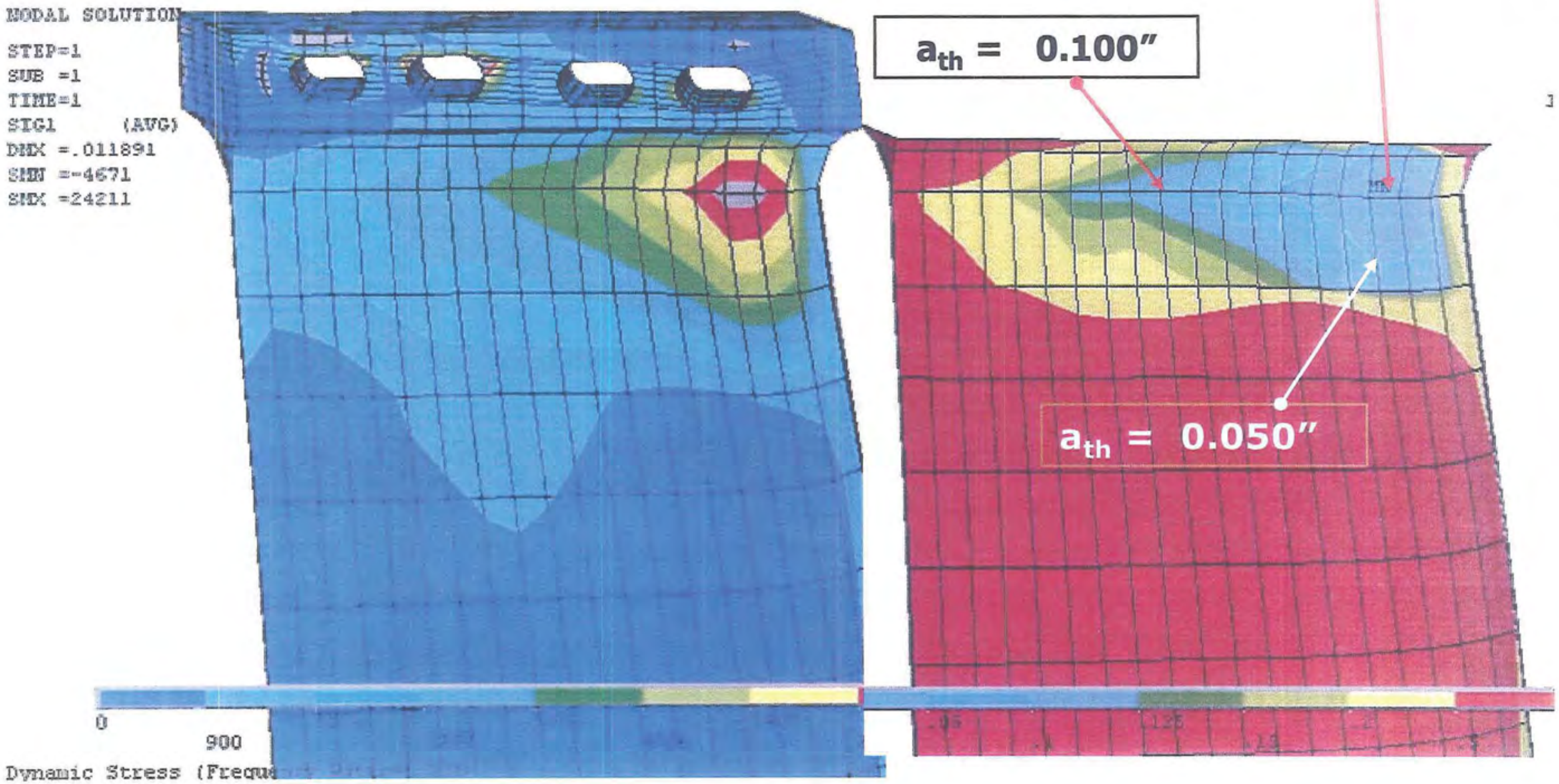
Resonant Stress Distribution
Mode B, f = 421 Hertz

TurboCare

GE blade is tuned at 421 hertz
420 hertz = 7/rev, Mode II Resonance

Minimum

a_{th} = **0.024"**



MEMORANDUM

INTERMOUNTAIN POWER SERVICE CORPORATION

TO: George Cross

FROM: Wes Bloomfield

DATE: June 12, 2008

SUBJECT: Recommendation to replace low pressure turbine last stage buckets

Due to the observed low pressure turbine L-0 or LSB (last stage buckets) leading edge erosion and the potential for bucket tip failure we recommend replacing these buckets on both units during the next major LP turbine overhauls. This recommendation is based on reliability concerns stemming from the observed leading edge erosion, bucket design, and material concerns. The service life of these buckets will be exceeded during the next LP turbine outage interval (20-30 yrs operating time). Avoiding the costs of forced outages due to LSB tip failure justifies replacing these buckets during the next scheduled LP overhauls. Replacing the LSB's on each unit during the next major LP turbine overhaul will require budgeting $6 million/unit for materials and installation and allocating up to six weeks to complete the work if all three sections (six rows) are replaced during a single outage.

Last Spring following the Unit 1 outage, GE recommended replacing the L-0 buckets in all three LP turbines during the next major outage (attachment p1). This recommendation was based on leading edge erosion observed during the outage inspections and the leading edge grooming done on these buckets in the 1999 outage. Since then we have been investigating the validity of this recommendation and options for bucket repair or replacement. We have also looked at the feasibility of replacing the entire LP turbine steam path.

The L-0 buckets installed in our LP turbines are GE 30" self shielded LSB's. These buckets are made entirely with hardened Jethete base material. GE started installing these buckets in the early 80's to reduce manufacturing costs. Unfortunately this hardening also reduces ductility and increases the tendency for crack propagation.

In 1999 and 2000, the leading edges on our LSB's were dressed to remove high spots in the leading edge erosion area. This was a preventive measure to remove stress risers where cracks could initiate. Since then, the leading edges have eroded to approximately the same depth as they were before dressing. It looks like this erosion rate is rapid initially until the surface roughens enough to hold a layer of water which acts as a buffer to reduce further erosion. After this point the erosion rate drops off.

The concern is that this additional (since 2000) erosion is getting deep enough to effect the integrity of the bucket tip. There is also evidence from finite element analyses conducted on these buckets that there is a 7X resonance node near the tip and close to the leading edge which could stimulate crack propagation from surface erosion pitting.

In 2004 several plants experienced failures of GE 33" and 30" self shielded last stage buckets due to high cycle fatigue cracks starting in the leading edge areas near the tip. These failures and the ensuing EPRI reporting prompted GE to issue TIL 1521-2 to address this problem.

TIL 1521-2 states that 5 tip loss failures have been identified in a total of 700 installed rows of self shielded LSB's. The mean time to failure of these 5 incidents was approximately 20 years. GE didn't give the average age of the total installations at the time the TIL was issued. The average age of the fleet using these buckets at the time of report was probably 20 years or less. Bucket service life is not solely time based, but is a function of operating conditions such as; severe cyclic duty, low steam quality, high back pressure, and repeated torsional events. Note that the longest any of these buckets have been in-service is less than 30 years.

U2 Inspections

During the Unit 2 outage just completed we were able to get a couple of specialists to inspect the LSB's. The general consensus from the GE technical director, plant personnel, and contractors who also inspected U1 last year, was that Unit 2's LSB leading edge erosion is not as severe as Unit 1's.

A consultant from MD&A with GE steam path design background was hired to inspect the Unit 2 LSB's and give us a recommendation on replacement. MD&A recommends replacing these buckets with shielded buckets to minimize the chance of a bucket failure (attachment p2-4). They did not state what the chance or probability of bucket tip failure would be if we do not replace them. We would have to be willing to live with the risk of bucket tip failures if we continued to operate with the existing buckets through the next LP outage interval.

GE brought in a steam path specialist to inspect and measure chord lengths on the Unit 2 LSB tip area to determine the extent of the erosion. These measurements and pictures were sent to the GE steam path engineers in Schenectady for evaluation. Although GE could not find other erosion measurements that were comparable to ours, they did state that our buckets are trending similar to buckets of the same age. GE provided plots comparing our LSB erosion to the erosion on 33.5" LSB's that have failed (attachment p5-7). These plots show that our erosion is higher, but they state that we can't draw any conclusions on life expectancy from this comparison because of the differences between 30" and 33.5" buckets.

After review of the Unit 2 inspection and measurements, GE is still recommending row replacement during the next suitable outage to mitigate risks. They stated that our LSB's are acceptable for further operation, but also recommended that we need to order spare buckets in case replacement is needed in short order (attachment p8).

TurboCare did not inspect the Unit 2 LSB's during the outage. After reviewing pictures of the leading edge erosion, they provided results of a finite element analysis and resonance node study they have conducted on GE's 30" unshielded LSB's. This study shows that there is a 7X operating speed resonance node close to the leading edge of these buckets (attachment p9-10). They believe that surface erosion in this area initiates the cracks that are propagated by the resonance node leading to bucket tip failure. Based on the extent of our erosion and the bucket design, TuboCare believes that we will have bucket tip failures.

Replacement Options

Earlier this year as a task item for the Greenhouse Gas Reduction Feasibility Study, we investigated the costs of replacing the entire LP turbine steam paths instead of L-0 bucket replacement. This would alleviate anticipated diaphragm repair, rotor bore inspection, and bucket root phased array inspection costs planned for the next LP turbine outages. The lowest price (Fall '07) for a complete LP turbine (3 sections) was $27.3 million installed. Note that this does not include outage extension costs as the shortest time quoted to replace all 3 sections in a single outage was six weeks. There is also potential fuel cost savings from improved LP section efficiencies with the new steam paths. The cost analysis comparing these alternatives shows that even with these fuel cost savings the cost of steam path replacement is at least two times the cost of last stage bucket replacement (attachment p11). The lead time for ordering new LP steam paths (rotor forgings) was 3.5 years for all suppliers we contacted last Fall.

Nearly all the major turbine parts suppliers offer replacement buckets for GE 30" LSB's installed in S2 and G2 turbines. GE offers self shielded (the same buckets that we have installed) replacements for $5.6 million per unit and shielded buckets for $6.7 million per unit. The best non-OEM price was $5.8 million by MD&A/Hitachi for their shielded buckets. Toshiba and TurboCare/Siemens offer shielded 30" LSB replacements and Alstom has a 30" LSB with induction hardened leading edges. All manufacturers can supply six rows of LSB's for the 2010 outage if the order is placed in mid 2009. Gathering the manpower and resources to do three section LSB replacements (six rows) in a single outage will require an earlier commitment.

DCS

cc: Mike Alley

BUCKETS

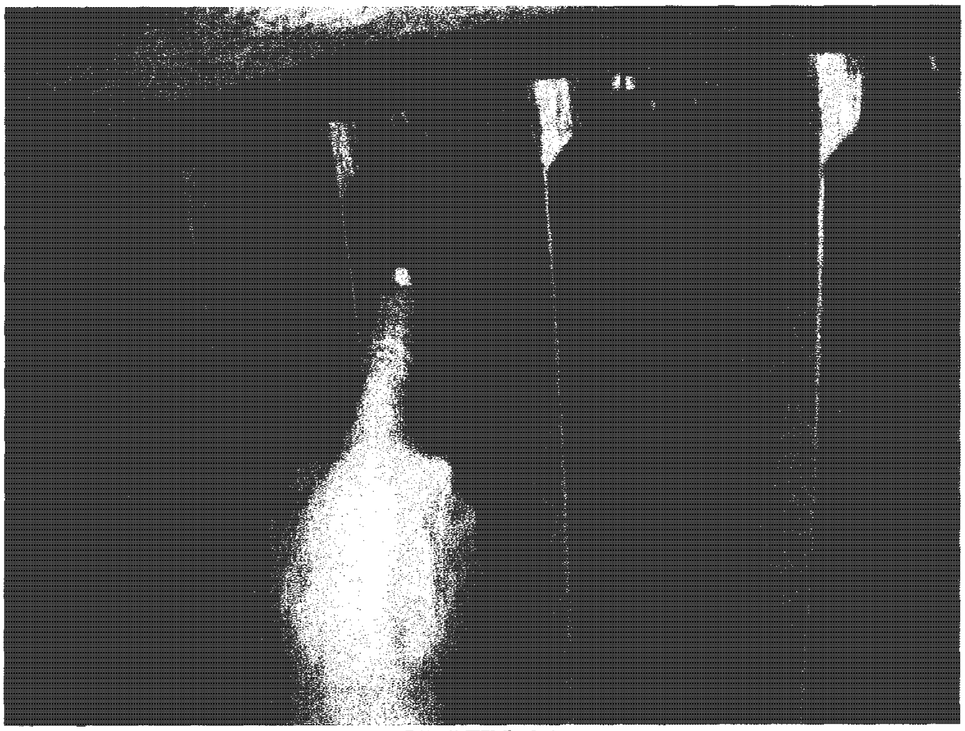
LP Buckets

Assembly; LP A,B and C

The L-0's on LP A, B, and C were visual and NDE examioned per TIL-1521 and GEK46354. As noted in past IPP QC records there is erosion on Inlet Side of all L-0 Buckets.

PRO comments are profile doesn't cause to much short term concern but should be replaced at next major outage.

Monitor LP L-0's per TIL-1521 and GEK46354 and replace on next major outage.



LP C TE L-0 1

MECHANICAL DYNAMICS and ANALYSIS, LTD

MECHANICAL DYNAMICS & ANALYSIS, LTD.
29 BRITISH AMERICAN BLVD., LATHAM, NEW YORK 12110
PHONE: (518) 399-3616 FAX: (518) 399-3929

www.MDAturbines.com

May 27, 2008

Mr. David Spence
Intermountain Power
850 West Brush Wellman Road
Delta, UT 84624

Tel: 435-864-6449
E-mail: dave-s@ipsc.com

SUBJECT: Inspection of Intermountain 2 Last Stage Buckets

Dear David:

In April, MD&A inspected the last stage buckets of Intermountain #2 in the hoods to provide Intermountain Power with a second opinion concerning the need to replace the buckets during a planned outage in 2010. Intermountain #2 is a GE S2 turbine with 30" last stage buckets and steam conditions of 2400#/1000°F/1000°F that went into service in 1987. The turbine was originally rated at 820 MW but you reported that the HP sections of both Intermountain units have been replaced with Alstom upgrades so the output is now higher.

INSPECTION

The 6 rows of last stage buckets were inspected by crawling through the manways into the exhaust hoods. The NDE of the last stage buckets had not been done.

The last stage buckets had a moderate amount of erosion on the leading edge near the tip, with no significant notches. It was reported that the erosion found at the last outage in 2000 was ground to remove the rough material. It should be noted that these 30" last stage buckets are GE's self-shielded design with no Stellite erosion shield.

The side entry covers had moderate erosion on the leading edge and moderate to heavy erosion on the swelled tenons on the discharge side. The worst swelled tenon erosion was on 20TB where the tenons were undercut at the root with the 3/32" thickness at the top reduced to .035" at the bottom.

The erosion on the trailing edge from the tie wire in is only slight, with no notches observed in the trailing edges.

Details of the last stage bucket inspection are shown in Table 1.

RECOMMENDATIONS/CONCLUSIONS

1. The last stage bucket erosion is not sufficient to require replacement if the buckets had erosion shields.

   - The level of erosion on the admission edge near the tip is less than that seen on shielded buckets which have continued to operate successfully. There were no significant notches observed in the leading edge which would produce stress concentrations and increase the possibility of crack initiation. Please note that cracks that do initiate in erosion shields on 30" continuously coupled buckets tend to stop in the ductile Inconel welds that attach the shields.

2. Replacing these unshielded L-0 buckets with shielded buckets would minimize the chance of a bucket failure.

   - Last stage bucket failures in the last few years seem to indicate that unshielded last stage buckets, like the buckets on the Intermountain units, may have a shorter life than shielded buckets. MD&A is aware of 4 tip failures of unshielded 30" last stage buckets in 2004 and 2005 but unaware of similar failures of the older shielded 30" continuously coupled buckets. Unlike the buckets with Stellite erosion shields, the unshielded buckets do not have a ductile Inconel layer to stop cracks that initiate on the leading edge. In addition, it appears that the hardness level of the buckets may have been increased and ductility decreased when the EBW shields were eliminated. The failures all occurred after cracks initiated on the leading edge near the tip and propagated across the blade until the tip broke off, causing a forced outage. There is suspicion that incorrect installation of replacement covers caused 2 of the 30" failures but it is likely that the negative aspects of the unshielded design contributed to the failures. Please note that MD&A inspected one of the 30" rows that had a bucket failure and found the leading edge erosion to be less than that of many 30" and 33 ½" L-0 rows previously seen that are operating reliably.

3. The last stage covers should be replaced if the buckets are not replaced.

   - The erosion of up to nearly 2/3 of the thickness of the discharge side tenons is severe enough to require replacement. Please note that special attention should be given to the swelling of the discharge tenons because incorrect swelling of the discharge tenons is considered the likely cause of two of the 30" L-0 failures. It appeared that extending the swelling too far toward the bucket restricted the ability of the bucket to untwist during service and increased the stress at the base of the trapezoidal section at the tip of the vane. The increased stress plus erosion notches in the leading edges combined to initiate cracks which resulted in tip failures on the unshielded 30" buckets. This special attention to the swelling process should also be applied to a new bucket installation if the new buckets have the same side entry cover design as the current last stage buckets.

4. Don't run with high back pressure.

   - Running with high back pressure increases the vibratory stresses in the buckets, especially during low load operation. Although the continuous coupling of the last stage buckets reduces the response to the stimulus from high back pressure, the

stress levels are still higher than those at normal operating conditions.

5. Remove the L-0 spill strip holder for cleaning if the opening is blocked with deposits.

   - The last stage bolted spill strip holder has a gap to the diaphragm that allows moisture on the outer sidewall of the diaphragm to go straight to the condenser without passing through the last stage buckets. If that passage is blocked, then the water must go through the last stage buckets, increasing the erosion on the admission vane tip. During the next LP inspection, a light can be placed on the inside of the passage and if it can be seen from the outside, then no action is required. If the light cannot be seen, then deposits have accumulated in the gap and the spill strip holders should be removed to allow the two surfaces to be blast cleaned. Bolts may break or require drilling, so you may want to have some on hand.

6. The discharge side L-0 bucket erosion is acceptable as is.

   - The erosion on the convex sides of some blades has not progressed to the point that there are notches in the trailing edge. If there are notches at future outages, then the trailing edge should be ground back to remove the notches.

Photographs of the Intermountain 2 last stage buckets are included as Figures 1-26. In addition, photographs of 2 of the 30" unshielded bucket failures are included as Figures 27-30.

The opportunity to serve Intermountain Power is appreciated. Please feel free to contact me if you have any questions.

Sincerely,

Jeffrey R Newton

Jeffrey R. Newton
Consulting engineer

Attachments

CC: D.E. Hatcher
B.R. Woody
P.D. Lamovec
P.L. Wilhelm
B. Allen
L. Molina

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IPP, Unit 2 LSB Erosion (270T151)

April 7, 2008

TIL 1521, LSB Erosion

Descriptive Statistical Analysis

	Mean	Standard Deviation	Min.	Max	Median
LPA TE1	0.059	0.033	0.026	0.131	0.049
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Notes:

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- Uniform erosion between ends within respective hoods (pg 6).

Two Sample T-Test and Confidence Interval

```
Two sample T for Erosion
End          N      Mean     StDev   SE Mean
GE          60    0.1043    0.0375    0.0048
TE          60    0.0981    0.0333    0.0043
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T-Test mu (GE) = mu (TE) (vs not =): T = 0.96  P = 0.34  DF = 116
Since P > 0.05 there is no statistically significant difference between sample means
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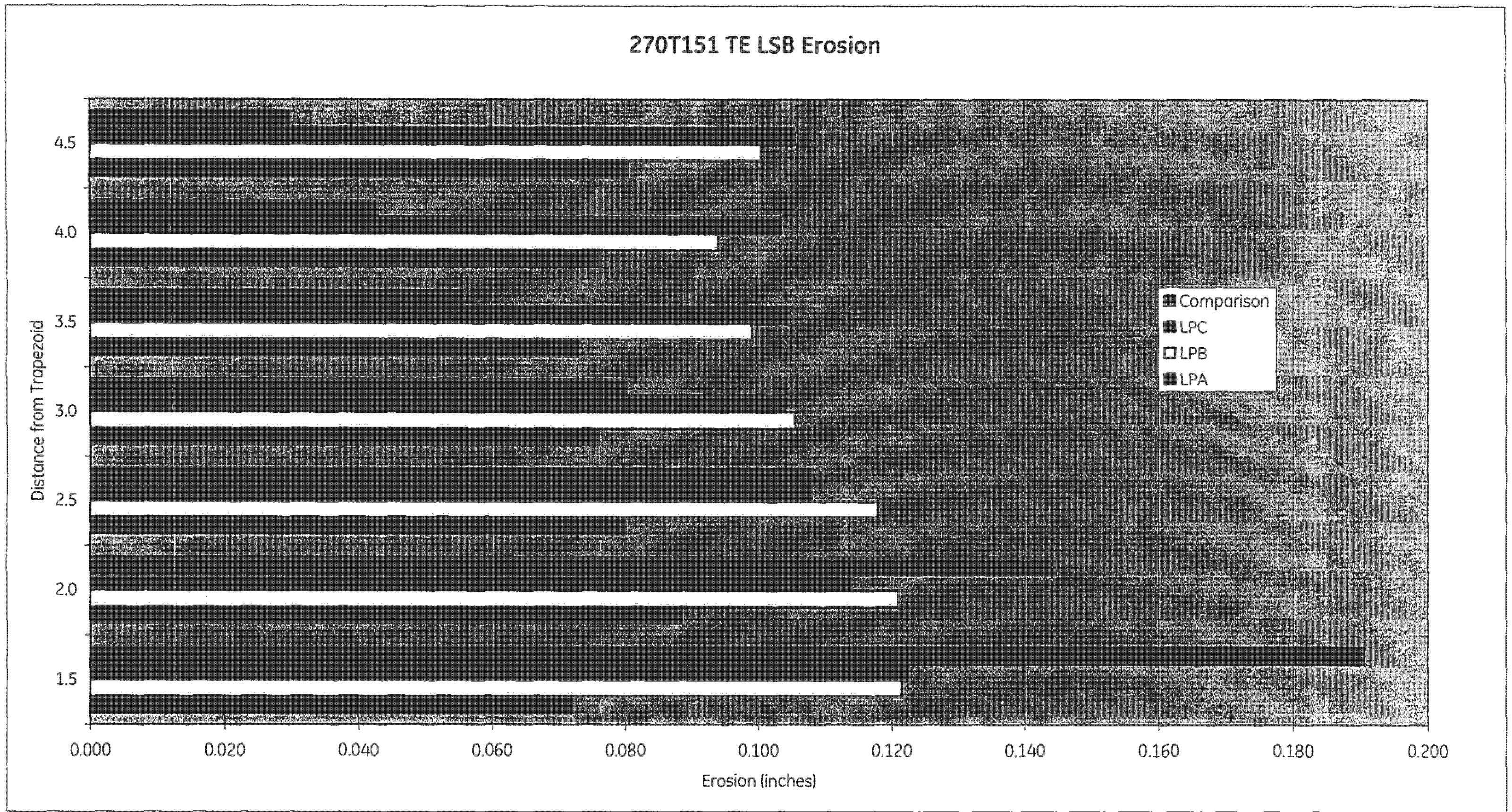
- Atypical erosion pattern from tip to approximately 6 inches down from the tip. Greatest erosion occurring at the 1.5 inch and 6 inch measuring points and lesser erosion in between these two points.

IPP, Unit 2 LSB Erosion (270T151)

April 7, 2008

Comparison of IPP's erosion to erosion measured on a 33.5" D8 turbine where LSBs were replaced.



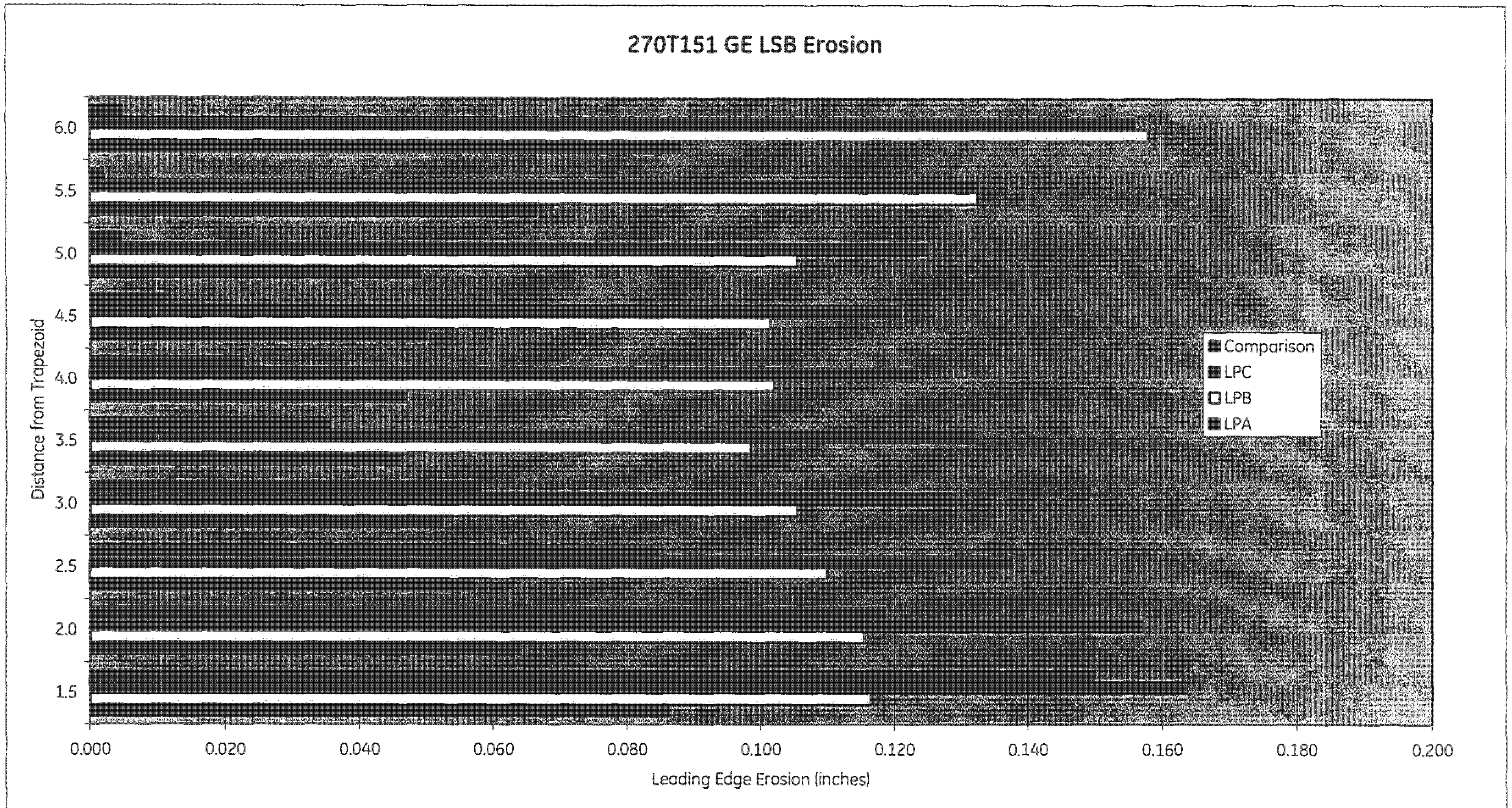
LSB Replacement Recommendation Memo attachment - page 6

IP7019358

imagination at work

IPP, Unit 2 LSB Erosion (270T151)
April 7, 2008

Comparison of IPP's erosion to erosion measured on a 33.5" D8 turbine where LSBs were replaced (continued).



Dave G.

MEMORANDUM

INTERMOUNTAIN POWER SERVICE CORPORATION

TO: George W. Cross

FROM: Wes J. Bloomfield WJB

DATE: June 16, 2008

SUBJECT: Recommendation to Replace Low Pressure Turbine Last Stage Buckets

Due to the observed low pressure turbine L-0 or LSB (last stage buckets) leading edge erosion and the potential for bucket tip failure, we recommend replacing these buckets on both units during the next major LP turbine overhauls. This recommendation is based on reliability concerns stemming from the observed leading edge erosion, bucket design, and material concerns. The service life of these buckets will be exceeded during the next LP turbine outage interval (20-30 yrs operating time). Avoiding the costs of forced outages due to LSB tip failure justifies replacing these buckets during the next scheduled LP overhauls. Replacing the LSB's on each unit during the next major LP turbine overhaul will require budgeting $6 million/unit for materials and installation and allocating up to six weeks to complete the work if all three sections (six rows) are replaced during a single outage.

Last Spring (2007) following the Unit 1 outage, GE recommended replacing the L-0 buckets in all three LP turbines during the next major outage (attachment p1). This recommendation was based on leading edge erosion observed during the outage inspections and the leading edge grooming done on these buckets in the 1999 outage. Since then we have been investigating the validity of this recommendation and options for bucket repair or replacement. We have also looked at the feasibility of replacing the entire LP turbine steam path.

The L-0 buckets installed in our LP turbines are GE 30-inch self shielded LSB's. These buckets are made entirely with hardened Jethete base material. GE started installing this type of buckets in the early 80's to reduce manufacturing costs. Unfortunately this hardening also reduces ductility and increases the tendency for crack propagation.

In 1999 and 2000, the leading edges on our LSB's were dressed to remove high spots in the leading edge erosion area. This was a preventive measure to remove stress risers where cracks could initiate. Since then, the leading edges have eroded to approximately the same depth as they were before dressing. It looks like this erosion rate is rapid initially until the surface roughens enough to hold a layer of water which acts as a buffer to reduce further erosion. After this point the erosion rate drops off.

The concern is that this additional (since 2000) erosion is getting deep enough to affect the integrity of the bucket tip. There is also evidence from finite element analyses conducted on these buckets that there is a 7X resonance node near the tip and close to the leading edge which could stimulate crack propagation from surface erosion pitting.

In 2004, several plants experienced failures of GE 33-inch and 30-inch self shielded last stage buckets due to high cycle fatigue cracks starting in the leading edge areas near the tip. These failures and the ensuing EPRI reporting prompted GE to issue TIL 1521-2 to address this problem.

TIL 1521-2 states that five tip loss failures have been identified in a total of 700 installed rows of self shielded LSB's. The mean time to failure of these five incidents was approximately 20 years. GE didn't give the average age of the total installations at the time the TIL was issued. The average age of the fleet using these buckets at the time of report was probably 20 years or less. Bucket service life is not solely time based, but is a function of operating conditions such as severe cyclic duty, low steam quality, high back pressure, and repeated torsional events. Note that the longest any of these buckets have been in-service is less than 30 years.

U2 Inspections

During the Unit 2 outage just completed, we were able to get a couple of specialists to inspect the LSB's. The general consensus from the GE technical director, plant personnel, and contractors who also inspected Unit 1 last year, was that Unit 2's LSB leading edge erosion is not as severe as Unit 1's.

A consultant from MD&A with GE steam path design background was hired to inspect the Unit 2 LSB's and give us a recommendation on replacement. MD&A recommends replacing these buckets with shielded buckets to minimize the chance of a bucket failure (attachment p2-4). They did not state what the chance or probability of bucket tip failure would be if we do not replace them. We would have to be willing to live with the risk of bucket tip failures if we continued to operate with the existing buckets through the next LP outage interval.

GE brought in a steam path specialist to inspect and measure chord lengths on the Unit 2 LSB tip area to determine the extent of the erosion. These measurements and pictures were sent to the GE steam path engineers in Schenectady for evaluation. Although GE could not find other erosion measurements that were comparable to ours, they did state that our buckets are trending similar to buckets of the same age. GE provided plots comparing our LSB erosion to the erosion on 33.5-inch LSB's that have failed (attachment p5-7). These plots show that our erosion is higher, but they state that we can't draw any conclusions on life expectancy from this comparison because of the differences between 30-inch and 33.5-inch buckets.

After review of the Unit 2 inspection and measurements, GE is still recommending row replacement during the next suitable outage to mitigate risks. They stated that our LSB's are acceptable for further operation, but also recommended that we need to order spare buckets in case replacement is needed in short order (attachment p8).

TurboCare did not inspect the Unit 2 LSB's during the outage. After reviewing pictures of the leading edge erosion, they provided results of a finite element analysis and resonance node study they have conducted on GE's 30-inch unshielded LSB's. This study shows that there is a 7X operating speed resonance node close to the leading edge of these buckets (attachment p9-10). They believe that surface erosion in this area initiates the cracks that are propagated by the resonance node leading to bucket tip failure. Based on the extent of our erosion and the bucket design, TuboCare believes that we will have bucket tip failures.

Replacement Options
Earlier this year as a task item for the Greenhouse Gas Reduction Feasibility Study, we investigated the costs of replacing the entire LP turbine steam paths instead of L-0 bucket replacement. This would alleviate anticipated diaphragm repair, rotor bore inspection, and bucket root phased array inspection costs planned for the next LP turbine outages. The lowest price (Fall '07) for a complete LP turbine (three sections) was $27.3 million, installed. Note that this does not include outage extension costs as the shortest time quoted to replace all three sections in a single outage was six weeks. There is also potential fuel cost savings from improved LP section efficiencies with the new steam paths. The cost analysis comparing these alternatives shows that even with these fuel cost savings the cost of steam path replacement is at least two times the cost of last stage bucket replacement (attachment p11). The lead time for ordering new LP steam paths (rotor forgings) was 3.5 years for all suppliers we contacted last Fall.

Nearly all the major turbine parts suppliers offer replacement buckets for GE 30-inch LSB's installed in S2 and G2 turbines. GE offers self shielded (the same buckets that we have installed) replacements for $5.6 million per unit and shielded buckets for $6.7 million per unit. The best non-OEM price was $5.8 million by MD&A/Hitachi for their shielded buckets. Toshiba and TurboCare/Siemens offer shielded 30-inch LSB replacements and Alstom has a 30" LSB with induction hardened leading edges. All manufacturers can supply six rows of LSB's for the 2010 outage if the order is placed in mid 2009. Gathering the manpower and resources to do three section LSB replacements (six rows) in a single outage will require an earlier commitment.

DCS/JKH:jmj
Attachments

cc: G. Mike Alley
Kelly Cloward

BUCKETS

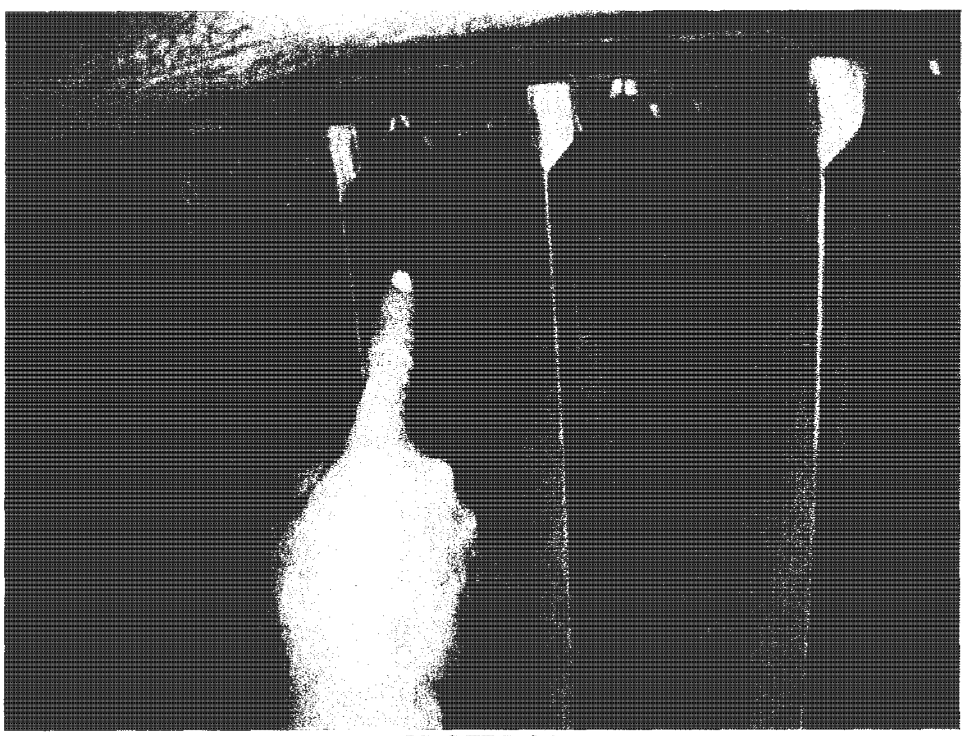
LP Buckets

Assembly; LP A,B and C

The L-0's on LP A, B, and C were visual and NDE examioned per TIL-1521 and GEK46354. As noted in past IPP QC records there is erosion on Inlet Side of all L-0 Buckets.

PRO comments are profile doesn't cause to much short term concern but should be replaced at next major outage.

Monitor LP L-0's per TIL-1521 and GEK46354 and replace on next major outage.



LP C TE L-0 1

MECHANICAL DYNAMICS and ANALYSIS, LTD

MECHANICAL DYNAMICS & ANALYSIS, LTD.
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www.MDAturbines.com

May 27, 2008

Mr. David Spence
Intermountain Power
850 West Brush Wellman Road
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Tel: 435-864-6449
E-mail: dave-s@ipsc.com

SUBJECT: Inspection of Intermountain 2 Last Stage Buckets

Dear David:

In April, MD&A inspected the last stage buckets of Intermountain #2 in the hoods to provide Intermountain Power with a second opinion concerning the need to replace the buckets during a planned outage in 2010. Intermountain #2 is a GE S2 turbine with 30" last stage buckets and steam conditions of 2400#/1000°F/1000°F that went into service in 1987. The turbine was originally rated at 820 MW but you reported that the HP sections of both Intermountain units have been replaced with Alstom upgrades so the output is now higher.

INSPECTION

The 6 rows of last stage buckets were inspected by crawling through the manways into the exhaust hoods. The NDE of the last stage buckets had not been done.

The last stage buckets had a moderate amount of erosion on the leading edge near the tip, with no significant notches. It was reported that the erosion found at the last outage in 2000 was ground to remove the rough material. It should be noted that these 30" last stage buckets are GE's self-shielded design with no Stellite erosion shield.

The side entry covers had moderate erosion on the leading edge and moderate to heavy erosion on the swelled tenons on the discharge side. The worst swelled tenon erosion was on 20TB where the tenons were undercut at the root with the 3/32" thickness at the top reduced to .035" at the bottom.

The erosion on the trailing edge from the tie wire in is only slight, with no notches observed in the trailing edges.

Details of the last stage bucket inspection are shown in Table 1.

RECOMMENDATIONS/CONCLUSIONS

1. The last stage bucket erosion is not sufficient to require replacement if the buckets had erosion shields.

   - The level of erosion on the admission edge near the tip is less than that seen on shielded buckets which have continued to operate successfully. There were no significant notches observed in the leading edge which would produce stress concentrations and increase the possibility of crack initiation. Please note that cracks that do initiate in erosion shields on 30" continuously coupled buckets tend to stop in the ductile Inconel welds that attach the shields.

2. Replacing these unshielded L-0 buckets with shielded buckets would minimize the chance of a bucket failure.

   - Last stage bucket failures in the last few years seem to indicate that unshielded last stage buckets, like the buckets on the Intermountain units, may have a shorter life than shielded buckets. MD&A is aware of 4 tip failures of unshielded 30" last stage buckets in 2004 and 2005 but unaware of similar failures of the older shielded 30" continuously coupled buckets. Unlike the buckets with Stellite erosion shields, the unshielded buckets do not have a ductile Inconel layer to stop cracks that initiate on the leading edge. In addition, it appears that the hardness level of the buckets may have been increased and ductility decreased when the EBW shields were eliminated. The failures all occurred after cracks initiated on the leading edge near the tip and propagated across the blade until the tip broke off, causing a forced outage. There is suspicion that incorrect installation of replacement covers caused 2 of the 30" failures but it is likely that the negative aspects of the unshielded design contributed to the failures. Please note that MD&A inspected one of the 30" rows that had a bucket failure and found the leading edge erosion to be less than that of many 30" and 33 ½" L-0 rows previously seen that are operating reliably.

3. The last stage covers should be replaced if the buckets are not replaced.

   - The erosion of up to nearly 2/3 of the thickness of the discharge side tenons is severe enough to require replacement. Please note that special attention should be given to the swelling of the discharge tenons because incorrect swelling of the discharge tenons is considered the likely cause of two of the 30" L-0 failures. It appeared that extending the swelling too far toward the bucket restricted the ability of the bucket to untwist during service and increased the stress at the base of the trapezoidal section at the tip of the vane. The increased stress plus erosion notches in the leading edges combined to initiate cracks which resulted in tip failures on the unshielded 30" buckets. This special attention to the swelling process should also be applied to a new bucket installation if the new buckets have the same side entry cover design as the current last stage buckets.

4. Don't run with high back pressure.

   - Running with high back pressure increases the vibratory stresses in the buckets, especially during low load operation. Although the continuous coupling of the last stage buckets reduces the response to the stimulus from high back pressure, the

stress levels are still higher than those at normal operating conditions.

5. Remove the L-0 spill strip holder for cleaning if the opening is blocked with deposits.

   - The last stage bolted spill strip holder has a gap to the diaphragm that allows moisture on the outer sidewall of the diaphragm to go straight to the condenser without passing through the last stage buckets. If that passage is blocked, then the water must go through the last stage buckets, increasing the erosion on the admission vane tip. During the next LP inspection, a light can be placed on the inside of the passage and if it can be seen from the outside, then no action is required. If the light cannot be seen, then deposits have accumulated in the gap and the spill strip holders should be removed to allow the two surfaces to be blast cleaned. Bolts may break or require drilling, so you may want to have some on hand.

6. The discharge side L-0 bucket erosion is acceptable as is.

   - The erosion on the convex sides of some blades has not progressed to the point that there are notches in the trailing edge. If there are notches at future outages, then the trailing edge should be ground back to remove the notches.

Photographs of the Intermountain 2 last stage buckets are included as Figures 1-26. In addition, photographs of 2 of the 30" unshielded bucket failures are included as Figures 27-30.

The opportunity to serve Intermountain Power is appreciated. Please feel free to contact me if you have any questions.

Sincerely,

Jeffrey R Newton

Jeffrey R. Newton
Consulting engineer

Attachments

CC: D.E. Hatcher
B.R. Woody
P.D. Lamovec
P.L. Wilhelm
B. Allen
L. Molina

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TIL 1521, LSB Erosion

Descriptive Statistical Analysis

	Mean	Standard Deviation	Min.	Max	Median
LPA TE1	0.059	0.033	0.026	0.131	0.049
LPA TE2	0.117	0.011	0.085	0.120	0.120
LPA GE1	0.067	0.020	0.048	0.113	0.060
LPA GE2	0.054	0.015	0.040	0.092	0.050
Averages	0.074				0.070
LPB TE1	0.110	0.011	0.095	0.126	0.110
LPB TE2	0.121	0.021	0.093	0.160	0.126
LPB GE1	0.127	0.017	0.112	0.167	0.121
LPB GE2	0.103	0.021	0.084	0.149	0.093
Averages	0.115				0.112
LPC TE1	0.117	0.019	0.104	0.162	0.110
LPC TE2	0.113	0.016	0.099	0.146	0.106
LPC GE1	0.142	0.014	0.127	0.166	0.136
LPC GE2	0.134	0.018	0.114	0.165	0.129
Averages	0.126				0.120

Notes:

- Statistical erosion agrees with relative back pressure between hoods, i.e. LPA has highest BP and least statistical erosion while LPC has lowest BP and highest statistical erosion: LPA – 0.062, LPB – 0.115, LPC – 0.126
- Uniform erosion between ends within respective hoods (pg 6).

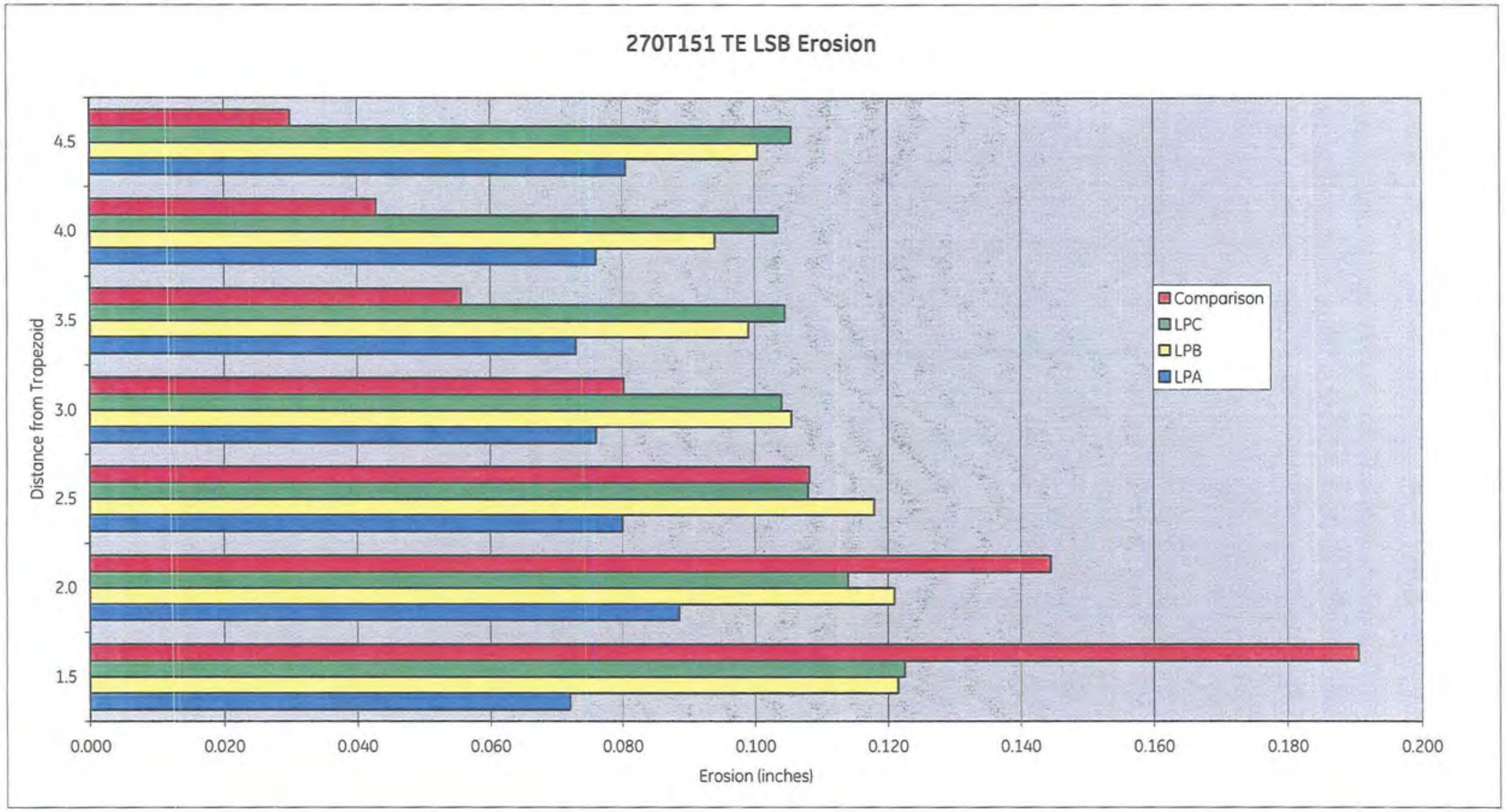
Two Sample T-Test and Confidence Interval

```
Two sample T for Erosion
End          N      Mean     StDev   SE Mean
GE          60    0.1043    0.0375    0.0048
TE          60    0.0981    0.0333    0.0043
95% CI for mu (GE) - mu (TE): ( -0.0066,  0.0191)
T-Test mu (GE) = mu (TE) (vs not =): T = 0.96  P = 0.34  DF = 116
Since P > 0.05 there is no statistically significant difference between sample means
```

- Atypical erosion pattern from tip to approximately 6 inches down from the tip. Greatest erosion occurring at the 1.5 inch and 6 inch measuring points and lesser erosion in between these two points.

IPP, Unit 2 LSB Erosion (270T151)
April 7, 2008

Comparison of IPP's erosion to erosion measured on a 33.5" D8 turbine where LSBs were replaced.

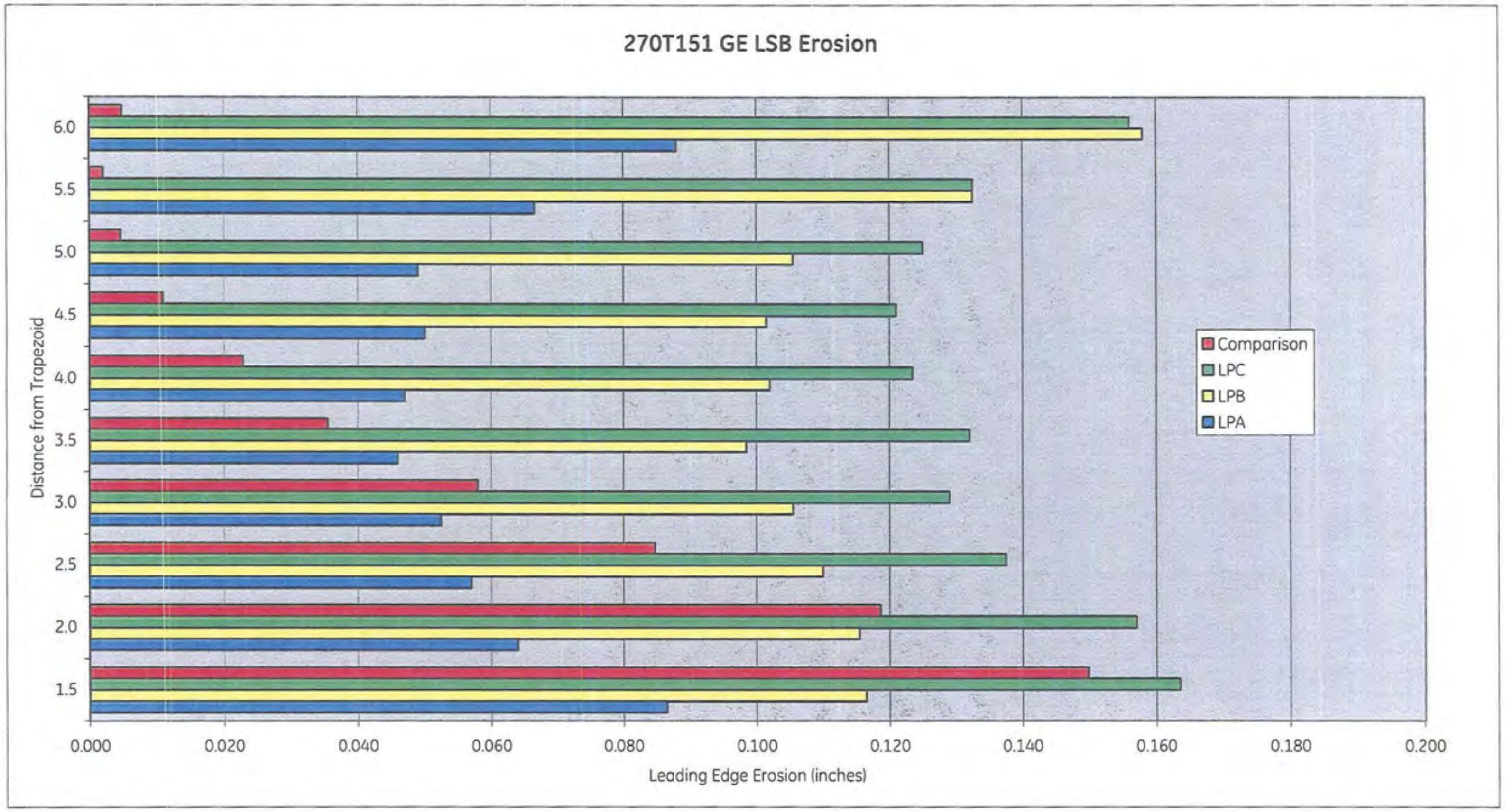


LSB Replacement Recommendation Memo attachment - page 6

IP7019368

IPP, Unit 2 LSB Erosion (270T151)
April 7, 2008

Comparison of IPP's erosion to erosion measured on a 33.5" D8 turbine where LSBs were replaced (continued).



LSB Replacement Recommendation Memo attachment - page 7

IP70193369

5/31/08

Dave,

I know you're waiting for this so I'm sending what I have:
<<270T151 LSB Erosion Statistics.ZIP>>
I've held onto this for a few days hoping to find other erosion measurements we could compare yours to, but I haven't found anything comparable. The one 'comparison' data I included here was taken from a Unit that had a LSB failure, but I really need to warn you about making any conclusions using the 'comparison' data. The inherent differences between yours and the 33.5" LSB are enough that we can't draw any correlation between erosion and life expectancy, i.e. the 33.5" LSB is approximately 3.5" longer than yours which gives it a much higher tip speed and the mass geometries at the tips are also different enough that it would differentiate problematic erosion thresholds. So, the 'comparison' erosion in this case is really only good for showing how your erosion is tracking relative to another unit that had an unfortunate LSB failure (i.e. tip liberation).

After John and I measured the Unit 2 LSBs last outage I ran a statistical analysis to confirm the data's reliability and then submitted the data to Schenectady for their review and recommendations. After reviewing the measurements, their conclusions have only subtle differences from the one in the outage report, which should be expected since our first opinion was based on less than optimal photos while the second opinion was based on precision measurements. Upon review of the measurements, Schenectady believes **the buckets are trending similar to other buckets of same age, but recommends ordering spare buckets in case a replacement is needed in short order.** They also recommend monitoring the buckets including the following:

- Perform mag particle test as convenient
- Visual inspections
- Measure erosion as convenient

These LSBs are acceptable for further operation, but to mitigate risks it is recommended to plan a row replacement during the next suitable outage. In your case - weighing the risks of an aging row of buckets and your LP section outages.

Look this over and let me know what else you may need.

Cecil

Cecil D. James PhD, P.E.
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West Region Applications Engineer
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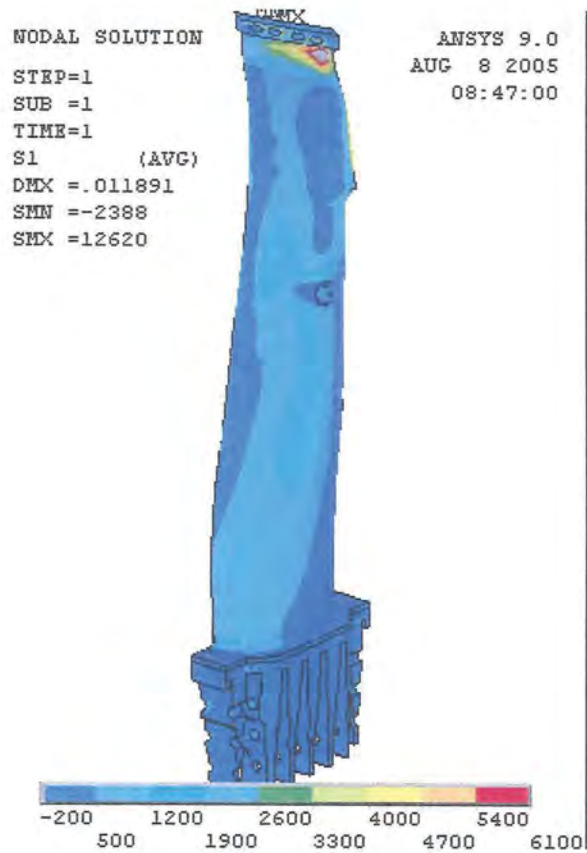
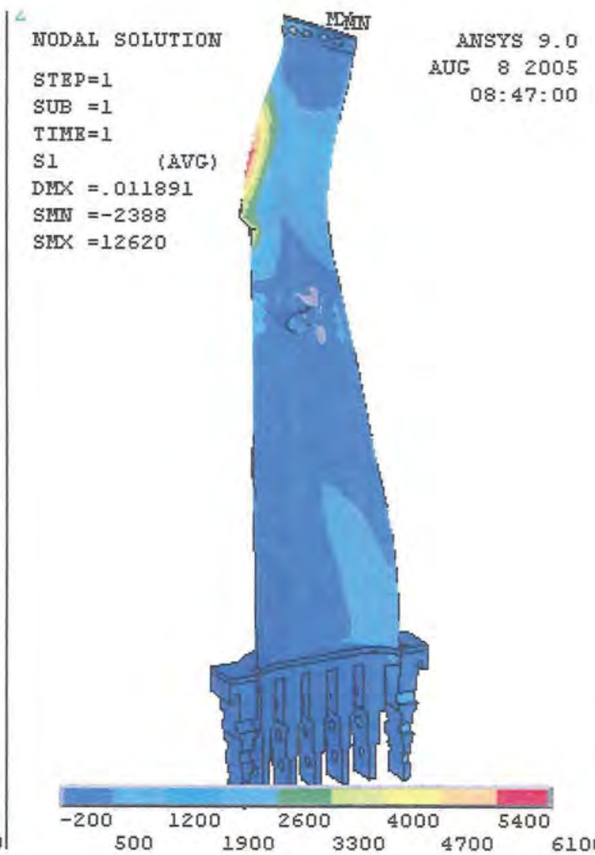


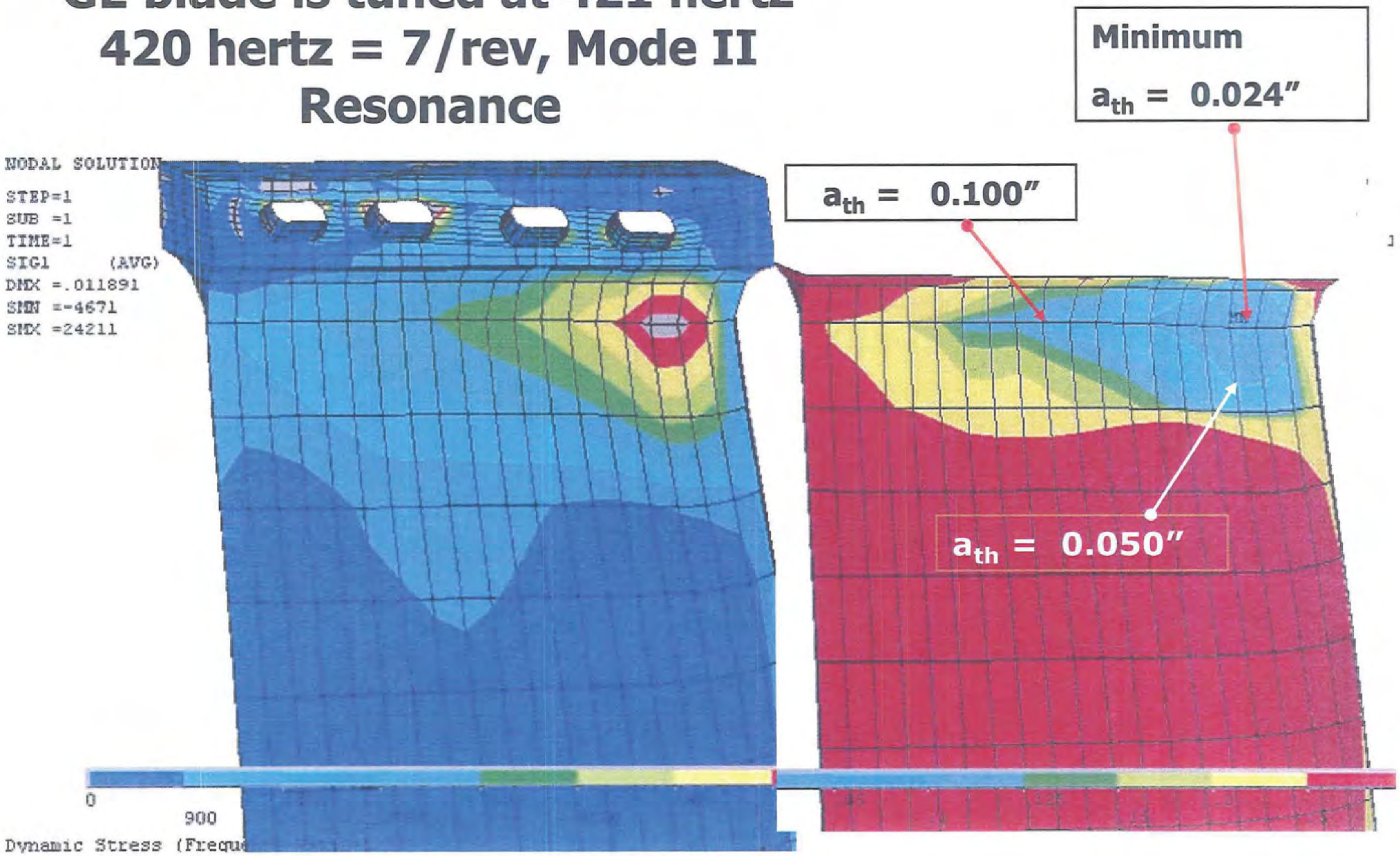


Resonant Stress Distribution
Mode B, f = 421 Hertz

GE's Mark 30" LSB

TurboCare

GE blade is tuned at 421 hertz
420 hertz = 7/rev, Mode II Resonance



LSB Replacement Recommendation Memo attachment - page 10

IP7019372

Unit 1 LP Turbine Outage Repair Options Comparisons

	Repair/Insp new L-0 yr 10	New L-0 Hitachi 30"	LP Retrofit GE 34.5"	LP Retrofit Hitachi 33"
Costs (2010 Outage)	A	B	C	D
L-0 bucket replacement		$5,885,605		
upgraded packing & rings	$467,482	$467,482		
packing & ring installation	$54,000	$54,000		
diaphragm repair (15th & 16th)	$881,540	$881,540		
rotor bore US inspection	$150,000	$150,000		
packing alignment	$68,250	$68,250		
dovetail phased array insp	$61,000	$37,500		
L-0 cover removal, insp, replacement	$407,850			
Total - Maintenance Repairs	$2,090,122	$1,658,772		
LP Turbine retrofit (3 sections)			$40,673,000	$27,300,000
PV L-0 bucket replacement (yr 10)	$4,400,137			
Typical outage 30 days (28+2 startup)				
2010 planned outage length (days)	35	42	42	42
2010 outage extension (days)	0	7	7	7
Outage extension cost	$5,651,931	$7,560,000	$7,560,000	$7,560,000
Total Costs	$14,232,312	$16,763,149	$48,233,000	$34,860,000
Annual Savings				
NPHR improvement (Btu/kwh)	42	47	67	108
L-0 stage efficiency		$61,249		
Turbine seals & packing	$494,705	$494,705		
Improved steam path & L-0			$789,173	$1,272,099
Annual coal burn reduction (tons/yr)	12,760	14,340	20,355	32,811
Annual C02 reduction (tons/yr)	30,879	34,702	49,260	79,404
CO2 reduction savings ($/yr)	$0	$0	$0	$0
Total annual savings ($/yr)	$494,705	$555,954	$789,173	$1,272,099
Project Cost				
PV total period savings	$4,230,410	$4,754,175	$6,748,511	$10,878,196
NPV project	-$10,001,902	-$12,008,974	-$41,484,489	-$23,981,804
Ecomomic Factors				
Payback period (total costs)	28.77	30.15	61.12	27.40
Payback period (upgrade costs only)	1.05	11.52	51.54	21.46
Rate of return (total costs)	-13%	-14%	-22%	-13%
Rate of return (upgrade costs only)	101%	0%	-20%	-9%

Legend
- Option A - New packing & rings, planned steam path repairs & inspections, inspect L-0 covers
- Option B - Same as Option A with replacement of L-0 buckets provided by Hitachi
- Option C - New (upgraded) LP turbine steam path provided by GE
- Option D - New (upgraded) LP turbine steam path provided by Hitachi 33" LSB new inner shell

Evaluation Criteria		
Outage year	2009	
Escalation (%)	3.00%	
Cost of Money (%)	6.04%	
Evaluation Period (yr)	10	
NPHR (Btu/kwh)	9500	
Net Capacity Factor (%)	90%	
Replacement Energy ($/MWh)	$50.00	
Fuel Cost ($/ton)	$38.77	38.77
Fuel Cost ($/mmBtu)	$1.66	1.66
CO2 tax ($/ton)	$0.00	
FY 06-07 Production Values		
Total fuel cost ($1,000's)	231,047.0	
Net station generation (gwh)	14,686.0	
Total coal burned (ktons)	5,959.9	
Coal HHV (Btu/lb)	11,686	
NPHR (Btu/kwh)	9,491	
Net Capacity Factor (%)	93.1	

5/31/08

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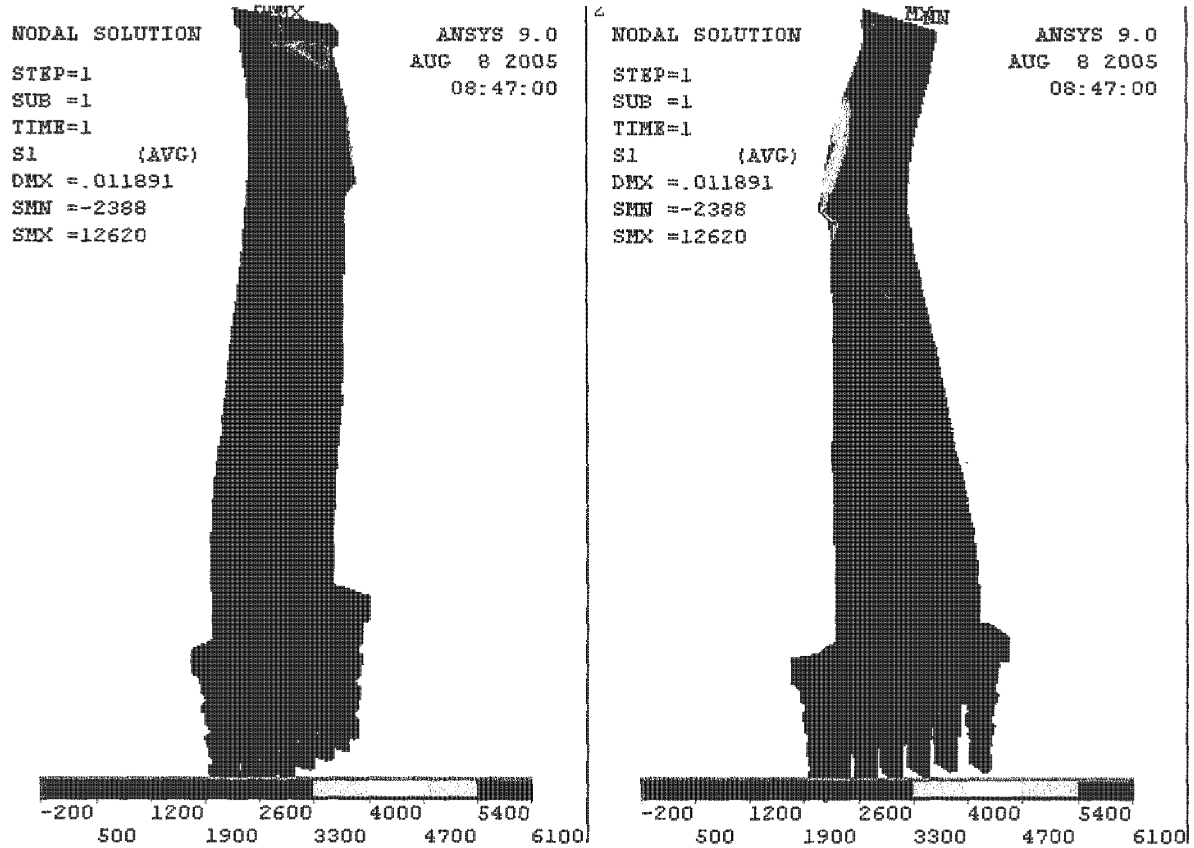

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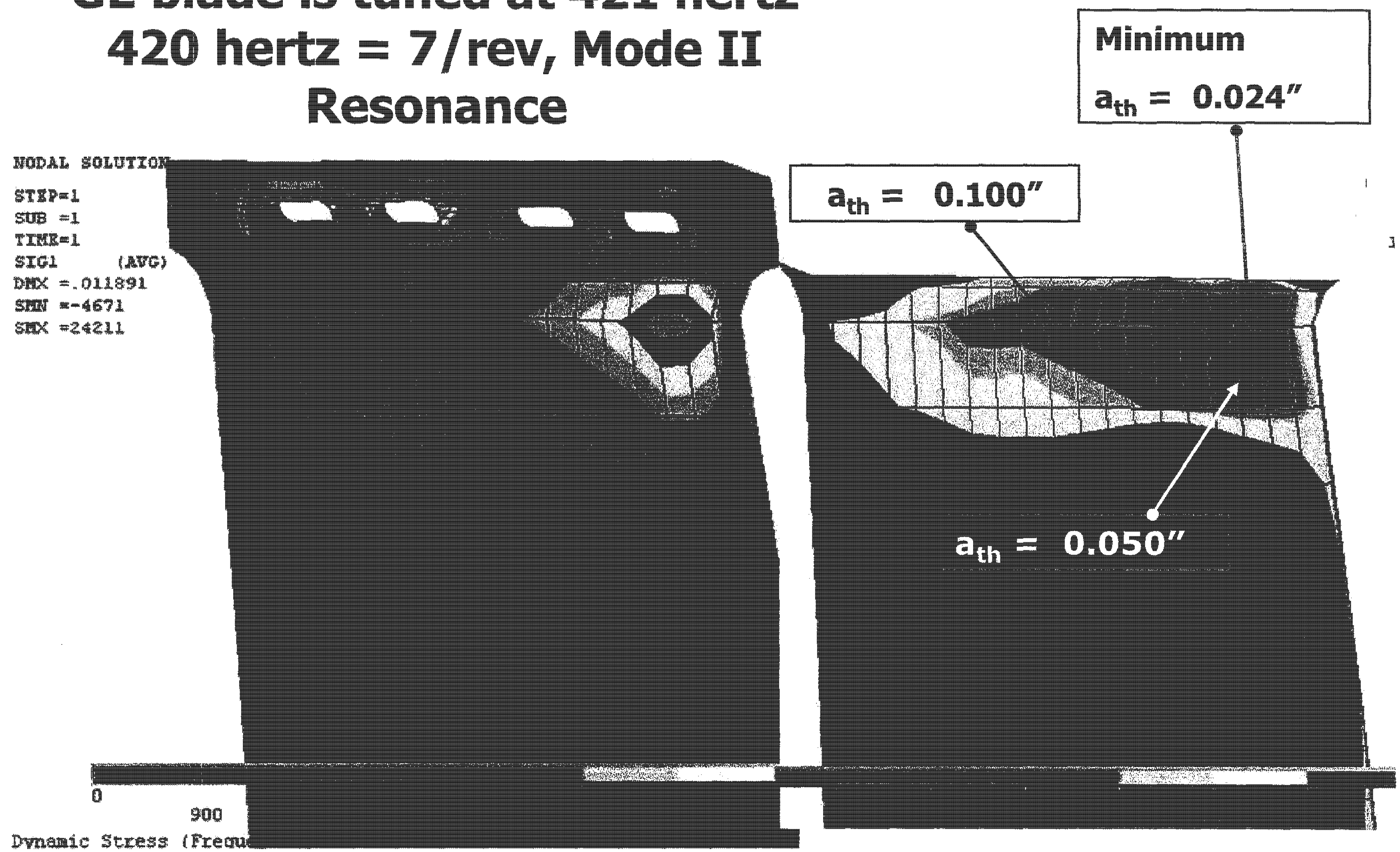

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Ecomomic Factors				
Payback period (total costs)	28.77	30.15	61.12	27.40
Payback period (upgrade costs only)	1.05	11.52	51.54	21.46
Rate of return (total costs)	-13%	-14%	-22%	-13%
Rate of return (upgrade costs only)	101%	0%	-20%	-9%

Evaluation Criteria		
Outage year	2009	
Escalation (%)	3.00%	
Cost of Money (%)	6.04%	
Evaluation Period (yr)	10	
NPHR (Btu/kwh)	9500	
Net Capacity Factor (%)	90%	
Replacement Energy ($/MWh)	$50.00	
Fuel Cost ($/ton)	$38.77	38.77
Fuel Cost ($/mmBtu)	$1.66	1.66
CO2 tax ($/ton)	$0.00	
FY 06-07 Production Values		
Total fuel cost ($1,000's)	231,047.0	
Net station generation (gwh)	14,686.0	
Total coal burned (ktons)	5,959.9	
Coal HHV (Btu/lb)	11,686	
NPHR (Btu/kwh)	9,491	
Net Capacity Factor (%)	93.1	

Legend

- Option A - New packing & rings, planned steam path repairs & inspections, inspect L-0 covers
- Option B - Same as Option A with replacement of L-0 buckets provided by Hitachi
- Option C - New (upgraded) LP turbine steam path provided by GE
- Option D - New (upgraded) LP turbine steam path provided by Hitachi 33" LSB new inner shell

IPSC CAPITAL BUDGET 10-YEAR PLAN
RENEWALS AND REPLACEMENTS
($1,000'S)

	Expenditure	2007-08 Budget	2008-09 Budget	2009-10 Estimate	2010-11 Estimate	2011-12 Estimate	2012-13 Estimate	2013-14 Estimate	2014-15 Estimate	2015-16 Estimate	2016-17 Estimate	2017-18 Estimate	2018-19 Estimate
Purchases	Miscellaneous Purchases	941	1,010	750	750	750	750	750	750	750	750	750	750
	Spare Stator Bars	5,000											
	Loader			500									
	30 Ton Crane					300							
	Dozer		1,800										
	Grader			350									
Total Capital Purchases		5,941	2,810	1,600	750	1,050	750	750	750	750	750	750	750
Projects	Unidentified Projects	867	2,266	1,295	745	2,470	4,150	3,400	2,000	1,500	1,000	12,000	12,000
	Modicon Upgrade	380	280										
	Concrete Circ Water Line Renewal*	3,220	665	855									
	BFPT Control System Replacement	680											
	Repair of External Horizontal Chimney	601											
	Stack Mercury Monitor	1,525											
	Cooling Tower Stack Repair	755											
	Sludge Conditioning Modifications	1,920											
	PLC Upgrade to DCS I/O (Phase I)	1,950	2,220										
	Unit 2 Burner Injector Replacement	2,579											
	Replace Obsolete Vibration Monitoring Equipment	200	300	300									
	Ground Water Remediation		800										
	Scrubber Reactor, Quench and Tank Overhaul		2,330	2,330	2,330	2,330							
	Replace Recovered Water Pipeline			865									
	Control Building HVAC			400									
	Scrubber HVAC			500									
	Primary Air Heater Basket Replacement and Seals			1,118	600								
	Cooling Tower Mechanical Renovation		delivery Fall 09	3,025	3,025								
	Generator Rewinds			7,000	2,000								
	LP Blade Replacement			6,000	6,000								
	VFD Motors for Condensate Pumps			1,312									
	Replace Scrubber Performance Analyzers				300	300							
	Switchgear Replacement					2,000	2,000						
	Generator Circuit Breaker Replacement				2,500	2,500							
	PLC Upgrade to DCS I/O (Phase II)					2,500	2,500						
	Stack Drains					650							
	Generator Relay Replacement					250	250						
	Stack Particulate Analyzers					1,000	1,000						
	IP Turbine Dense Pack					6,000	6,000						
	Stack CO Monitors						400	400					
	Neural Net Boiler Optimization Controls						1,200	1,200					
	Pulverizer Uprate - Rotating Classifiers						2,500	2,500	2,500	2,500			
	Unit 1 Burner Replacement						6,000						
	Superheater Tube Replacement							7,500	7,500				
	AQCS to DCS System								3,000	3,000			
	Reheater Tube Replacement									8,000	8,000		
	Clean and Repair Bottom Ash Ponds										11,000		
	HP Feedwater Heater Replacement										5,000	5,000	
	Economizer Replacement											8,000	8,000
Total IGS Capital Projects		14,677	8,861	25,000	17,500	20,000	26,000	15,000	15,000	15,000	25,000	25,000	20,000
	Batteries and Chargers		300										
	345 kV Breaker Replacements									2,000			
	REDAC RTU's		420										
	DC Control Replacement		1,500	11,500									
	ICS Misc Capital Projects	510	15	70	70	70	70	70	70	70	70	70	70
Total ICS Capital Projects		510	2,235	11,570	70	70	70	70	70	2,070	70	70	70
Total Capital Projects		15,187	11,096	36,570	17,570	20,070	26,070	15,070	15,070	17,070	25,070	25,070	20,070
'otal Additions and Betterments		21,128	13,906	38,170	18,320	21,120	26,820	15,820	15,820	17,820	25,820	25,820	20,820

Notes
1. Only projects or purchases greater than $250,000 are placed on the 10-year plan. Projects under $250,000 are grouped as miscellaneous projects.
2. * indicates portions of the project were completed in years not shown on this plan.

TIL 1521

TIL 1521-2
GE ENERGY SERVICES TECHNOLOGY
CUSTOMER TECHNOLOGY SERVICES
3 NOVEMBER 2005

Compliance Category - M
Timing Code - 5

TECHNICAL INFORMATION LETTER

JETHETE MATERIAL SELF SHIELDED LAST STAGE BUCKETS

APPLICATION

GE Steam Turbines with Jethete material self shielded last stage buckets.

PURPOSE

Recently, a technical paper was authored to describe select customers experience with 30" and 33.5" last stage self-shielded buckets. Following receipt by GE, a review was conducted to better understand the conclusions drawn. GE is publishing this TIL to inform all customers of GE findings and recommendations based on fleet historical evaluation and analysis, and to provide current inspection recommendations for in-service last stage buckets.

Compliance Category

O - Optional	Identifies changes that may be beneficial to some, but not necessarily all, operators. Accomplishment is at customer's discretion.
M - Maintenance	Identifies maintenance guidelines or best practices for reliable equipment operation.
C - Compliance Required	Identifies the need for action to correct a condition that, if left uncorrected, may result in reduced equipment reliability or efficiency. Compliance may be required within a specific operating time.
A – Alert	Failure to comply with the TIL could result in equipment damage or facility damage. Compliance is mandated within a specific operating time.
S – Safety	Failure to comply with this TIL could result in personal injury. Compliance is mandated within a specific operating time.

Timing Code

1	Prior to Unit Startup / Prior to Continued Operation (forced outage condition)
2	At First Opportunity (next shutdown)
3	Prior to Operation of Affected System
4	At First Exposure of Component
5	At Scheduled Component Part Repair or Replacement
6	Next Scheduled Outage
7	Optional

BACKGROUND DISCUSSION

Last stage (L-0) buckets are the final row of rotating components on Low Pressure Steam Turbines. These buckets come in a variety of vane lengths and configurations dependent on the application or size of the machine in which they are utilized.

GE has incorporated several design changes in our L-0 bucket applications over the years. These have included the development of new technologies and the use of advanced steam path performance improvements (Appendix 1). One of these technologies was the introduction and use of Jethete base material, commercially known as M152, for last stage buckets. This material was initially utilized as a bucket base material, which was used in conjunction with stellite shielding on the leading edge, affixed through either a soldering or a welding process.

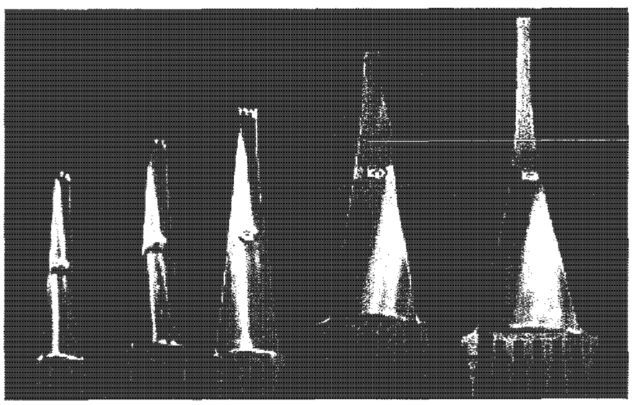


Figure 1: **L-0 Self Shielded Jethete Buckets**

In the 1970's, following extensive investigation into the nature and prediction of erosion rates, GE began manufacturing buckets that utilized this material without stellite shields. This design was termed a self-shielded configuration. While erosion is expected to be slightly higher in this design, the material is expected to provide a comparable service life. Since the mid 1980's, this design has been incorporated on almost all configurations of last stage buckets on 3000 and 3600-rpm units.

GE has gathered and analyzed fleet historical data on over 1200 installed rows of last stage buckets. For comparative analysis, this population was broken down into previous shielded designs and self shielded designs. This offered a representative comparison of reliability over time as a function of in service failures in both populations with the following results.

1. 5 tip loss failures have been identified in a total population of over 700 installed rows of self shielded design LSB's with a mean time to failure of ~ 20 years.
2. 1 tip loss failure has been identified in a total population of over 500 rows of shielded design LSB's with meant time to failure of ~ 25 years.

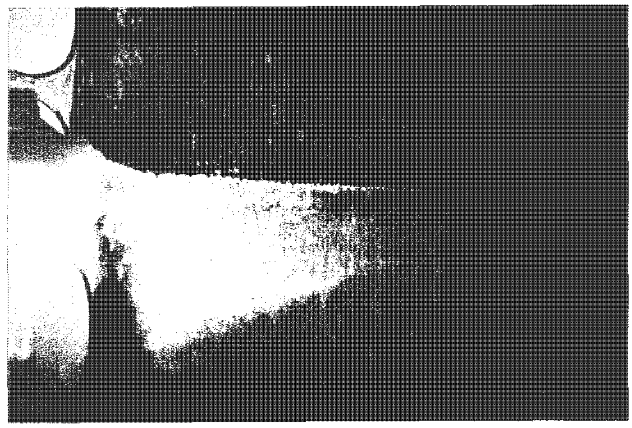


Figure 2: Erosion Profile on a Self Shielded Jethete Material L-0 Bucket

3. All failures have been limited to the 30" and the 33.5" populations.
4. 4 out of 5 failures identified in the self-shielded population were found on the generator end LP-B row of their respective units.

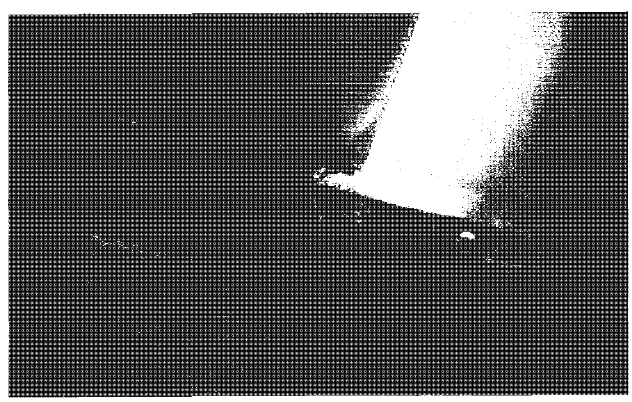


Figure 3: A Tip Loss

5. High cycle fatigue was identified as the root cause of tip crack propagation on failures where material analysis was performed.

Following this effort, it was determined that the nature of these failures can be site specific and that operational or mechanical factors may be contributors.

Bucket life is not defined on a time-based scale. It is a function of operational conditions and operating environment. Specific contributors, which result in accelerated erosion, component degradation, and significant cyclic stimuli include:

- Severe cyclic duty
- Low steam quality / poor inlet conditions
- High backpressure
- Repeated torsional events

RECOMMENDATIONS

An inspection of the last stage bucket area can reveal a number of problems, including excessive last stage erosion, water induction, stress corrosion cracking, mechanical failure, and/or foreign material damage. Currently, there are recommendations in place for periodically inspecting L-0 Buckets for structural integrity in previously published TIL-630. These recommendations should continue to be followed. The TIL recommends annual inspections of L-0 Buckets to monitor their physical conditions visually.

Components that should be inspected include tie-wires and tie-wire sleeves, erosion shields, bucket vanes, peened or inserted covers, dovetails, and spill strips. Findings from these periodic inspections should be provided to GE for engineering review and recommendation relative to component condition and to identify any need for additional monitoring or immediate corrective action.

Customers should continue to follow operational guidelines surrounding steam inlet conditions and backpressure listed in their unit specific Operation and Maintenance Manuals.

Evaluation should be conducted to assess any potential torsional conditions that may impact the steam turbine. If they exist, contact your local GE service representative for review.

In addition to these current recommendations, GE has developed an in-situ Non-Destructive Evaluation process utilizing a magnetic particle inspection technique to help identify any defects forming in the erosion areas on the tips of L-0 blades. This inspection should be performed based on the physical condition of the blades. By performing recommended annual inspections and forwarding findings to GE Engineering, an assessment can be provided to determine when and how often this test should be performed for specific machines.

Findings relative to continued evaluation, including inspection methods, criteria, and periodicity will be communicated in subsequent revisions to this TIL.

PLANNING INFORMATION

Compliance
- Compliance Category: M
- Timing Code: 5

Manpower Skills
NA

Parts
NA

Special Tooling
NA

Reference Documents
TIL 630

Previous Modifications
NA

Scope of Work
NA

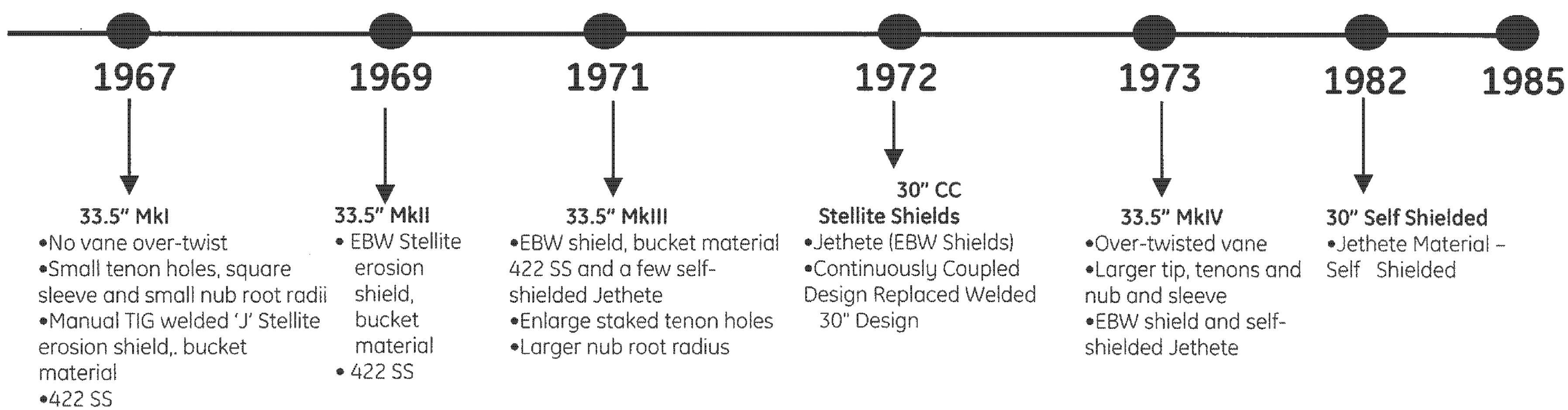
Contact your local GE Energy Services representative for assistance or for additional information.

NOTE: *If you would like to receive future TILs by email, contact your local GE Energy Services representative for assistance.*

more info
do spring 09

APPENDIX 1- GE LSB DESIGN EVOLUTION

1971: 33.5" LSB(MkIII) Jethete material introduced. Engineering studies started.
1972: 30" LSB with EBW stellite shields affixed to the leading edge.
1973: 33.5" LSB(Mk IV) offered based on field experience. Self-shielded design.
1982: 30" LSB self-shielded design offering.
1985: Change to sole use of Jethete material and self-shielded design on all LSB's.
-EBW shielded buckets stellite shield change outs / repairs experience
-Predicted to provide durability / adequate overall part life



TIL COMPLIANCE RECORD

Compliance with this TIL must be entered in local records. GE requests that the customer notify GE upon compliance of this TIL.

Complete the following *TIL Compliance Record* and FAX it to:

TIL Compliance
FAX: (678) 844-3451
Toll free FAX: 1-888-896-TILS (1-888-896-8457)

TIL COMPLIANCE RECORD	For Internal Records Only #
Site Name:	Customer Name:
Customer Contact Information	**GE Contact Information**
Contact Name:	Contact Name:
Address:	Address:
Email:	Email:
Phone:	Phone:
FAX:	FAX:
Turbine Serial Number(s):	

INSTALLED EQUIPMENT	TIL Completed Date:
	100% TIL Completed:
Description:	

Unit Numbers:	Part Description:	Part Number	MLI Number

Comments:

NOTE: *If there are any redlined drawings that pertain to this TIL implementation, please FAX the drawings along with this TIL Compliance Record.*

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GE values your opinions and comments.

GE requests that you complete the *User Satisfaction Survey* below to help us better serve you with accurate and timely information on your equipment.

Complete the following *TIL Compliance Record* and FAX it to:

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GE Customer Technology Services
FAX: (678) 844-6737
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Rate the following based on a scale of 1 to 5, where **1** is Excellent and **5** is Poor.

2. Please rate how well this document informed you of the technical issue.

1 **2** **3** **4** **5**

3. Please rate the overall effectiveness of this TIL.

1 **2** **3** **4** **5**

Comments / Suggestions:

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GE Customer Technology Services
FAX: (678) 844-6737
Toll free FAX: 1-866-604-2668

EPRI 1014598

IP7019386

Productivity Improvement for Fossil Steam Power Plants, 2006

1014598

Final Report, December 2006

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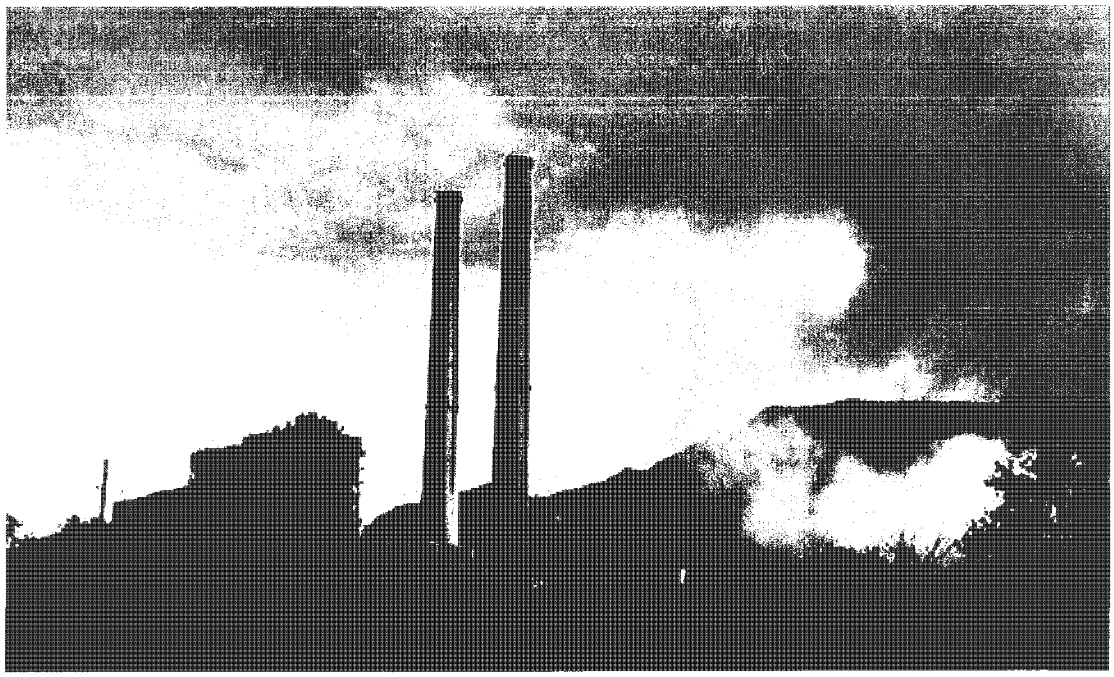
PacifiCorp Detect Cracks at Huntington 1 Unit in Self-Shielded Last Stage Turbine Blades Leading to Recommendations on Repairs and Inspection Procedures



The PacifiCorp plant at Huntington, Utah, had a failure in 2004 at its 477 MW unit 1. This was an in-service failure of a 33.5" self-shielded last stage turbine bucket. The failure occurred when the unit was at steady-state full load conditions. The crack initiated at an erosion crevice on the leading edge of the blade and traveled across the blade foil.

Issues/Goal (Text From [1])

During August 2004, the PacifiCorp Huntington Station Unit 1 GE D8 turbine experienced an operational failure of a self-shielded 33.5" last stage bucket, resulting in a 30-day unplanned outage and a $4 million bucket replacement and repair effort. The failure appears to have resulted from a high-cycle fatigue crack that developed at a leading edge erosion crevice and propagated to failure before detection. There had been four similar failures of self-shielded buckets in units owned by Southern Company and AmerenEnergy (AEG).

In the mid 1970s and early 1980s, GE began manufacturing the 26", 30" and 33.5" stellite-shielded last stage buckets from Jethete M152 material with a measured hardness of about 370 HB (vs. 327 HB spec.), and eliminated the electron beam weld-attached (EBW) stellite erosion shield. This version of bucket design was termed by GE to be 'self-shielded' because raising the material hardness was supposed to resist erosion along the leading edge of the bucket in the same manner as the stellite shield. The self-shielded buckets resist erosion, but present a different wear pattern than the stellite shielded buckets. When a self-shielded bucket is eroded, the nose of the blade contains numerous sharp crevices that have very small micro cracks at the bottom of the crevices. Once the micro cracks start to grow, the crack propagation rate appears to be greater in the harder material than in the more ductile, shielded buckets. This increases the probability of a crack reaching critical flaw size before detection.

It was noted that PacifiCorp, Southern Company and AEG have not had a single in-service failure of the earlier version 30" or 33.5" stellite-shielded last stage buckets, although many rows of those buckets have been in service for 30-35 years. It appears therefore that the self-shielded buckets have a shorter service life and are more prone to in-service failures than the EBW stellite-shielded buckets.

For the aging (1960-1985) GE fleet of over 200 turbines with over six hundred rows of 30.0" and 33.5" last stage buckets, it is expected that last stage bucket replacement could be an issue in the coming years. The preferred choice for replacement buckets may be the stellite-shielded version, but currently no one is manufacturing them. It may be prudent to delay replacement of existing buckets until shielded replacement buckets are again manufactured as an option.

This case study analysis seeks to assess the failure causes, and recommends ways for future protection from erosion of last stage buckets.

Key Conclusions

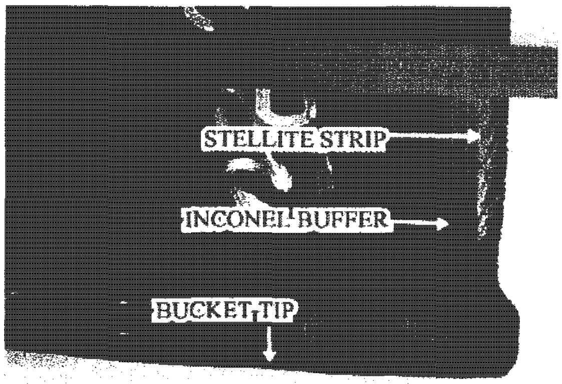
The self-shielded bucket elevated material hardness appears to shorten the service life and pose an increased risk of in-service bucket failures. There is also a possibility that both shielded and self-shielded buckets may develop cracks in areas outside the erosion zone near the blade tip. Cracks between the base and mid-blade may pose the risk of a catastrophic failure.

One course of action [2] is to gather a fleet history, develop standards for inspection techniques and intervals, and to provide options for bucket replacement. More specifically:

1. For fleet owners and operators of GE turbines with 26", 30" and 33.5" last stage buckets, inventory units to determine bucket design, material, age and inspection and repair history.
2. Establish a user's group to collect information about the fleet operating history of the GE 26", 30" and 33.5" last stage buckets. The operating history would be used to determine the service life expectancy of buckets based on size, design, material type and unit operating history.
3. Encourage development of in-situ inspection techniques that test the entire bucket, from base to tip for cracks and accumulated fatigue damage.
4. Establish recommended inspection intervals based on bucket design, material, age and service duty.
5. Encourage contingency planning to prepare plant personnel for the course of action to be taken when in-situ inspections disclose cracks in buckets.
6. Propose that manufacturers develop the capability to manufacture stellite-shielded buckets as a replacement option.
7. Conduct a cost/benefit analysis comparing the shielded and self-shielded last stage buckets.

Solutions and Problems

There have been a number of design evolutions and material changes in the 33.5" last stage buckets since they were first introduced in 1960:

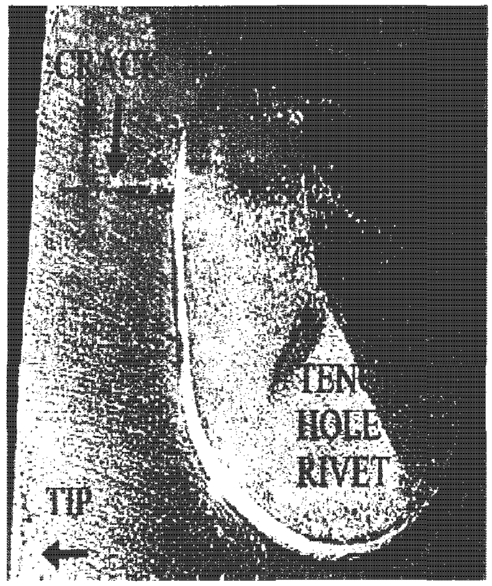


33.5" shielded bucket. The stellite erosion shield and Inconel buffer extend approximately ½" from the nose across the face of the blade.

1. **MK I** – The original design was a 422 Stainless Steel bucket with a hand-welded on formed stellite shield. Welding was done using the TIG process with Inconel as the filler metal.
2. **MK II** – This design was similar to the MK I, but the stellite erosion shield, which was a solid formed bar along the outer blade nose, was attached by electron beam welding with Inconel filler. **MK III** – Same as MK II except larger nub for tie wire – 422 Stainless Steel bucket.
3. **MK IV** – (est. 1973) Changed bucket material to Jethete M152 and continued attachment of stellite erosion shield. Slightly higher tensile strength; hardness approximately the same as the 422 SS, 327 HB. Over-twist design, larger nub, cover with larger tenon holes.
4. **MK IV** – (est. mid to late 1970s) Discontinued attachment of the stellite shield. Bucket was termed *'self-shielding'* because the hardness of material was increased to 360 - 370 HB to resist erosion without using a stellite shield. Elimination of welded stellite shield may have reduced the bucket manufacturing costs potentially by as much as 20%.
5. **MK IV** Heavy – (est. introduced in 1990) – same material as MK IV and has heavier tenon boss and blade length extended to 34.5", self-shielded. If retrofit, this modification requires machining the last stage diaphragm to accommodate the larger bucket diameter, and replacement of the flow guides.

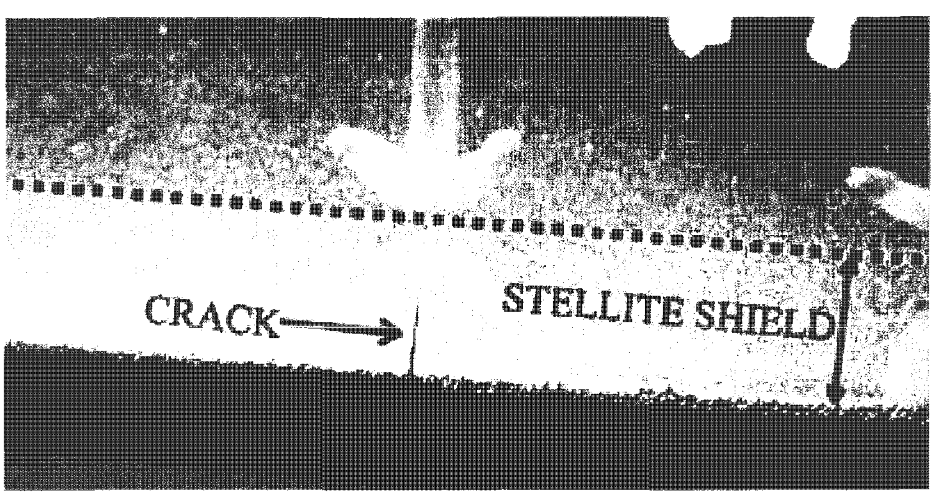
The 33.5" buckets in general have had a good fleet reputation except for cracks that occur at the tip of the buckets. Each bucket has a riveted spacer block that acts to continuous-couple the buckets at speed. It is not uncommon for cracks to start in the tenon hole and propagate to the tip of the blade. However PacifiCorp is unaware of any instances where tenon-hole cracks have resulted in a significant in-service blade failure. Note the Dave Johnston Unit 4 LP LSB tenon-hole crack indication, from April 2005.

It has been GE's recommended practice that buckets with the tenon cracks be replaced rather than weld-repaired. It was demonstrated in 2003 at the Dave Johnston Station that these tenon-hole cracks could be successfully weld repaired and post-weld heat-treated without removing the buckets from the rotor. Over the past 25 years, self-shielded Jethete M152 buckets have replaced the ones with cracks at tenon holes. This resulted in a mixture of bucket types in rows that previously had only stellite-shielded buckets.



Operational Factors Causing Cyclic Fatigue

Elevated backpressure, low-load operation, saturated steam washes and unit start-ups and shutdowns can cause steam flow disturbances that allow blade vibration and induce cyclic fatigue damage of the blade material. The resistance to the fatigue damage that a bucket sustains will vary depending on material and hardness. Accumulated fatigue damage until recently could not be measured by non-destructive test methods so problems were typically not detected until cracks develop at stress risers such as tenon holes, pits from corrosion, and erosion crevices, etc. In the Jethete M152 self-shielded buckets, there is no Inconel attachment-weld buffer zone to stop a leading-edge fatigue crack. The increased hardness of the self-shielded blade material seems to contribute to accelerated crack growth, reducing the opportunity of pre-failure detection. This presents challenges when attempting to plan bucket replacement cycles for near-end of the service life, and to assess the risk associated with postponing bucket replacement until cyclic fatigue cracks develop.



IP7019391

In the stellite-shielded buckets (both 422 SS and Jethete) fatigue cracks that develop in the stellite shield zone of the blade generally do not propagate beyond the Inconel barrier of the attachment weld and can be removed by buffing or light grinding. See above the figure of a leading edge crack in the satellite shield of a Dave Johnston Unit 4 bucket.

In the Jethete M152 self-shielded buckets, there is no Inconel attachment-weld buffer zone to stop a leading-edge fatigue crack. The increased hardness of the self-shielded blade material seems to contribute to accelerated crack growth, reducing the opportunity of pre-failure detection. This presents challenges when attempting to plan bucket replacement cycles for near-end of the service life, and to assess the risk associated with postponing bucket replacement until cyclic fatigue cracks develop.

Risk Assessment

Operating history, crack location, bucket design and bucket material type are keys to evaluating the probability and consequences associated with operating a unit until the cycle fatigue damage is manifested. Cracks located in three different areas of the bucket may pose different levels of risk depending on bucket style and material:

1. **Spacer-block Tenon Cracks:** Although there is a rather high incidence of tenon cracking, PacifiCorp is unaware of any incidents of a tenon crack that has liberated a spacer block and caused significant turbine or condenser damage. The risk of an in-service failure from this type of crack is considered low. This type of cracking has been found in all generations of the 33.5" PacifiCorp last stage buckets.
2. **Leading-edge bucket cracks along erosion zone near bucket tip:** This area of the bucket suffers moisture-related erosion. The erosion crevices provide numerous crack-initiation sites for high-cycle fatigue damage.
   - **Stellite-shielded buckets:** Both the 422 Stainless and Jethete shielded buckets are resistant to crack propagation because cracks typically stop at the Inconel zone of the attachment weld, which allows an opportunity to detect and remove the crack during normal overhaul cycles. The risk of an in-service failure from this type of crack is viewed as 'low' in shielded blades.
   - **Self-shielded buckets:** Cracks that develop in this zone of the self-shielded buckets are more frequent because the erosion crevices are deeper and sharper than in the shielded buckets, and the cracks seem more likely to propagate quickly and grow to critical crack size than in the more ductile shielded buckets. The risk of an in-service failure from this type of crack appears to be significantly greater than in a shielded bucket.
3. **Cracks in bucket areas outside of the tenon holes and tip leading edge:** At the Dave Johnston and Huntington Stations, cyclic fatigue cracks of this nature were found and addressed before failure in five buckets since 1997. Two cracks were in stainless shielded buckets, and three were in Jethete self-shielded buckets, so it is assumed that each style and material of 33.5" bucket is susceptible to these high-cycle fatigue cracks occurring outside the stellite shield zone. The frequency of crack occurrence is less than scenarios 1 and 2, but the consequences of an in-service failure are potentially catastrophic if a blade separates between the base and mid-bucket. Cracks in self-shielded Jethete blades with hardness greater than 350 HB are of concern because they seem more likely to reach critical crack size before detection than in the more ductile shielded buckets with a hardness less than 350 HB.

PacifiCorp Unit History for 33.5" LSB's

PacifiCorp owns and operates four GE Model D8 turbines and has ownership in three other D8 turbines not operated by PacifiCorp. The units, which were all commissioned between 1972 and 1983, have been in base load operation. The turbines are tandem-compound reheat units, with double-flow low-pressure sections. The last stage buckets are 33.5" in length and weigh approximately 38 lbs. each, exerting a centrifugal force in excess of 470,000 pounds of force at synchronous speed. The cover piece (or tenon block) exerts over 2000 pounds of force at speed.

In Summary

Dave Johnston Unit 4 - 330 GMW, 1971 - Glenrock, Wyoming (MK II buckets, shielded, 422 Stainless Steel).

- Pre 2003: One cracked sleeve was replaced, 22 spacer blocks were replaced because of rivet cracks, and one tenon-hole crack was weld repaired.
- 2003: (32 years service life last stage buckets) Dismantled inspection - Cracks from high-cycle fatigue were found in the leading edge of two buckets, approximately 4-6" from the base of the bucket. Those two buckets were replaced with new buckets. Additional crack indications were found along the stellite shields of eight buckets; these cracks were ground out and polished. The cracks in the stellite did not progress beyond the Inconel buffer zone of the attachment weld. Other buckets were cracked at the tenon holes and were weld repaired. The unit had been inadvertently operated at or slightly above the 5.0" Hg condenser backpressure limit for two months in the year before the dismantled inspection and it is thought that the elevated backpressure was a contributor to the development of high-cycle fatigue damage in the blades.
- 2005: (34 years service life last-stage buckets) Last stage buckets were replaced with self-shielded Jethete buckets.

Hunter Unit 3 – 475 GMW, 1983 – Castle Dale, Utah (shielded Jethete M152 buckets)

Pre 1998: No previous last stage bucket repairs. Turbine HP/IP section had the advanced-design steam path modification and boiler capacity was increased, which caused an equivalent steam-flow increase of 10% at the turbine inlet. A GE evaluation of the last stage buckets showed loading to be 5% above normal because of the increased steam flow and the reheat attemperation-spray flow. Based on their design review and the fleet operating history of the 33.5" buckets, operation at the proposed limits was approved.

2004: Post Huntington Unit 1 failure - an in-situ dye penetrant test of the bucket leading edges was completed and no crack indications were found.

2005: Since the 1998 turbine modification, the unit has been unable to sustain the condenser backpressure levels that were typical before the modification (less than 3.0"Hg). Backpressure at full load is typically 4.0"– 5.5"Hg. The issue of what effect operating at elevated backpressure would have on L-0 bucket loading and stability is still being reviewed. In April, the last stage buckets were inspected by Reinhart and Associates using an eddy current test probe – no cracks were detected.

Huntington Unit 1 – 470MW, 1977 – Huntington, Utah

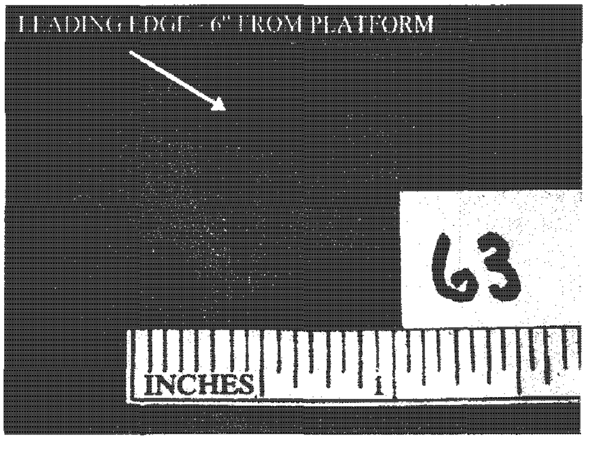
Pre 1997: From available historic records, it appears the only last stage bucket activity was replacement of dovetail pins.

1997: During the planned dismantled inspection, cracks were found in three Jethete self-shielded last stage buckets. The crack locations were as follows:

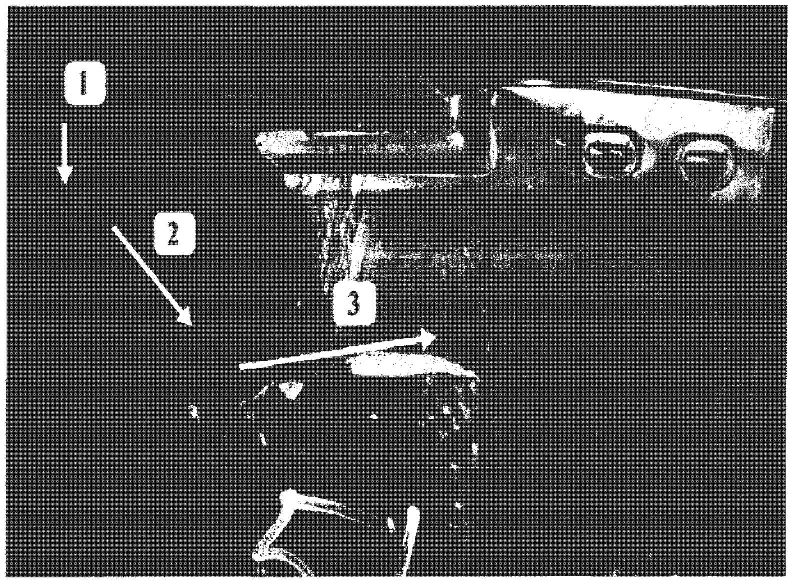
1. Leading edge, 6" from base platform
2. Trailing edge, 20" from base platform
3. Trailing edge, <1" from tip of blade

The cracked buckets were replaced and then sent to Radian (now M&M Engineering) for metallurgical analysis. The analysis showed the crack failure mechanism to be high cycle fatigue and the cracks did not occur at the highest stress area of the blades.

2004: In August, HTG1 suffered an in-service failure of a 33.5" self-shielded last stage bucket. The failure occurred when the unit was at steady-state full load conditions. The crack initiated at an erosion crevice on the leading edge of the blade and traveled across the blade foil. M&P Laboratories, Schenectady, NY, determined high-cycle fatigue was the failure mechanism. When the bucket tip and spacer block separated, collateral damage occurred to the other buckets in that stage and the mating diaphragm. The mating diaphragm and other buckets in the failure row sustained damage from the liberated tip and spacer block, but collateral damage was minimal. Turbine shaft vibration did not exceed a level that would initiate damage of seals. Because of leading edge erosion, and cracks that were found at the tenon holes of 30 other buckets, the decision was made to replace both rows of the Huntington L-0 buckets with new MK IV self-shielded buckets. Huntington Unit 1 had a combination of shielded and self-shielded buckets.



The crack in Bucket 63 was readily visible, having cracked through-wall for a length of over 1" at the leading edge of the bucket, approximately 6" from the base of the bucket. The consensus of experts involved at that time was that an in-service failure was imminent and that the blade mass involved may have resulted in gross imbalance and extensive turbine damage.



Repair Costs

The bucket replacement was accomplished in a 30-day period at a cost of approximately $4 million. There were additional losses from lost generation sales opportunities, and due to the purchase of replacement power for the 470MW unit.

Huntington Unit 2 – 470 GMW, 1977 – Huntington, UT

This unit has a mix of shielded and self-shielded Jethete M152 buckets.

Pre 1992: No record of last stage bucket repairs.

1992: Scheduled dismantle inspection. Spacer-block tenon-hole cracks were found in 23 last stage buckets. GE replaced all 23 buckets with Jethete M152 self-shielded buckets.

1998: Eleven last stage buckets with tenon-hole cracks were replaced with buckets removed and repaired during the 1992 dismantle. Those buckets had been repaired by removing approximately 3" of the tip of the bucket and replacing with a new tip and a new stellite strip was submerged-arc welded on the buckets.

Units With Full or Partial Ownership, But Not Operated by PacifiCorp

Arizona Public Service Cholla Unit 4 (375 GMW, 1981)

This unit has no reported history of 33.5" last stage bucket problems. Buckets are shielded Jethete. The unit has been operated at elevated backpressure, 4.5-5.0"Hg. Measures are being taken to inspect the buckets in-situ at the first opportunity. Since the unit has a history of high backpressure operation, the last-stage bucket service life may be shortened and buckets should be periodically monitored for cracks.

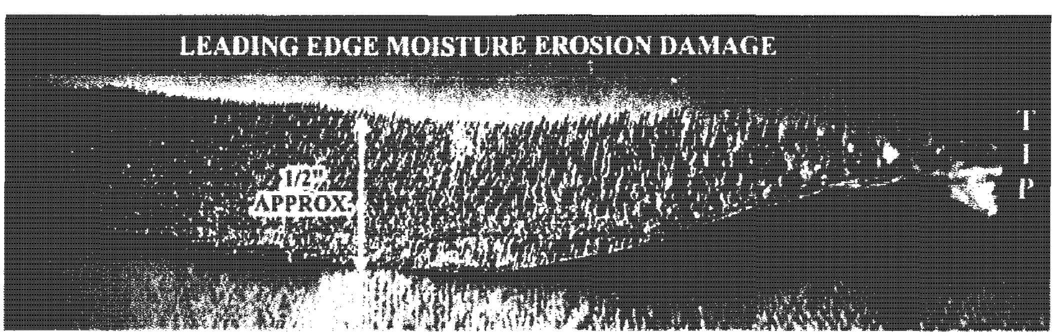
Tri-State Generation Craig Units 1 & 2 (411 MW, 1980 & 1979)

These units have 33.5" last stage buckets, shielded, but material type has not been determined. The history shows welded repair of several buckets that had cracks originating at the tenon-holes. The Unit 1 last dismantled inspection was in 2003 and Unit 2 in 2004; that was the last time buckets were inspected. Periodic in-situ inspections are being considered, and would be done during extended forced outages or planned outages.

Other Companies' Experiences

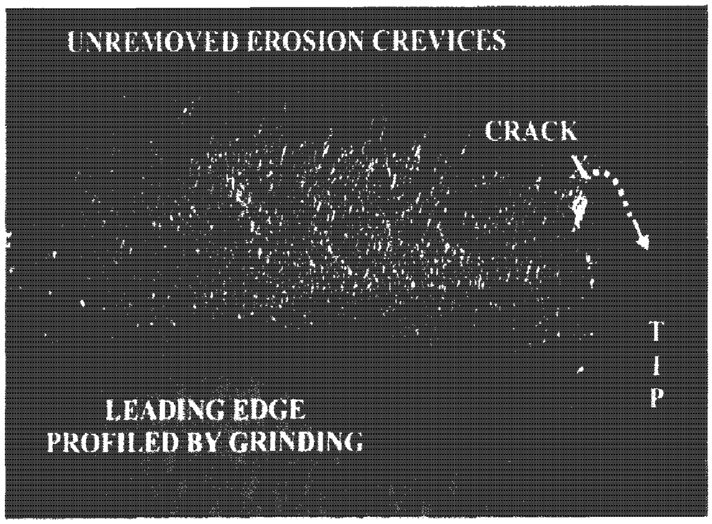
AmerenEnergy (AEG) Coffeen Unit 2 (590 MW)

Ameren owns and operates the Coffeen Power Station in Coffeen, Illinois. The 590 MW Coffeen Unit 2 is a swing-load unit that operates in a range of 40-100% rated load. It has a cyclone sub-critical once-through boiler that makes it difficult to maintain reheat temperature at lower loads. Backpressure is typically below 3" Hg, but there are brief excursions in the summer to 3.5" Hg. The GE Model G2 steam turbine has two double flow low-pressure turbines with 30" last stage buckets. The unit was placed in commercial service in 1972 and operated for 22 years before the last stage buckets were replaced in 1993 because of tie wire cracking. Heavy erosion of the satellite-shielded buckets was also observed. The replacement buckets were the GE Jethete M152 'self-shielded' buckets, and experienced heavy moisture erosion along the leading edge. The erosion wastage created crevices along the leading edge, with the deepest crevices near the tip of the buckets.



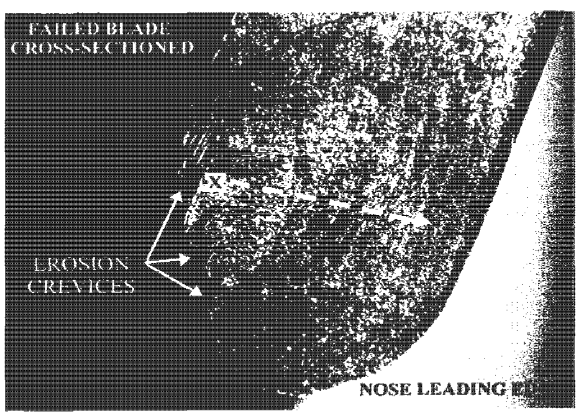
In March of 2004, when the replacement buckets were approximately nine years old, the first in-service failure of these buckets occurred. While the unit was in operation, the tip of a bucket liberated and necessitated a two-week outage for repairs and replacement of several buckets. An analysis of the failed bucket disclosed that a crack had initiated in a moisture-erosion crevice approximately ½" from the original nose of the bucket, near the tip where the deepest erosion crevices existed. The crevice notch served as an initiation site for a high-cycle fatigue crack.

After the failure, the last stage buckets were inspected, the damaged buckets were replaced, and attempts were made to eliminate the worst of the foreign object damage along the bucket leading edges near the tip of the buckets by grinding and contouring the erosion areas. The unit was returned to service with the intent of operating it until a scheduled dismantled inspection in February 2005.

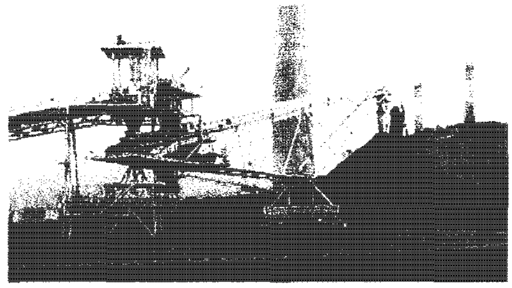


But, during the first week of January 2005, another last stage bucket failed while the unit was in service. The crack location and failure mechanism was nearly identical to the failure that had occurred previously. The failure was in a blade that had been contoured in March.

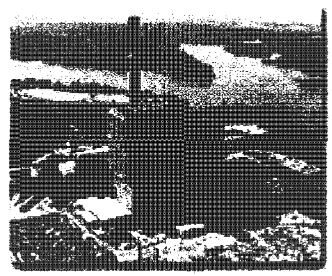
So, in less than ten months since all last stage buckets had been inspected and determined to be suitable for service, a crack had developed and progressed to failure. The failure necessitated a six-week early start of the scheduled 2005 overhaul. During the overhaul, both rotors were replaced with new GE rotors that have the 33.5" self-shielded Jethete M152 last stage buckets.



Units Featured With Start-Up Dates



PacifiCorp Huntington, 2X 477 MW units, 1977, Huntington, UT



PacificCorp, Dave Johnston, Unit 4, 330 MW, 1971, Glenrock, WY

Ameren, Coffeen Unit 2, 590 MW, 1972, Coffeen, IL

TriState, Craig, Craig, CO Units 1, 2, 2x411 MW, 1979/1980

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1. ***"The PacifiCorp Experience with General Electric Turbine 33.5" Last Stage Bucket"***, T. Kurtz TK, Inspection Service, CO, P. Sabec, PacifiCorp, Dave Johnston Plant, WY, EPRI TGUG, August 22, 2005, Denver, CO.
2. AEIC conference, Barry Cunningham, Sr. VP of Electric Operations, May 5, 2005, Dallas, TX.

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This case study at PacifiCorp's Huntington Unit 1, and at other units that utilize GE 33.5 inch last stage buckets, illustrates an issue of growing importance when operating steam turbines today.

Moisture erosion is a continuing problem in the final stages of LP turbines, especially as the wetness levels increase with improved efficiency and the tip diameters increase. Local hardening of the blade tip leading edge and the use of shields have been reasonably successful in the past. In the case of stellite shields, replacement of eroded shields can cost-effectively extend the life of the blades.

In the case described above, the self-shielded blades were heat-treated to a high hardness level throughout the entire component, not just the leading edge. The result is a blade that is not sufficiently tolerant to erosion notching. It was also noted in a subsequent stress analysis that there was a high probability of vibratory stress at the same vane location as the erosion notches – further limiting the expected life of this blade. The solution is to install a modified blade design that has a stellite shield, and to ensure that the vibration modes are well-tuned to avoid resonance with harmonics of shaft speed.

For those plants managing risk of fatigue cracking in blade vanes, like that described above, there is a promising new NDE technology designed to detect pre-crack fatigue damage in thin cross-sections such as airfoils. The ultrasonic method will be benchmarked by EPRI in the research project described in EPRI Supplemental Project Notice 1013029 dated July 2006. If successful, plant owners will for the first time be able to determine when a blade is likely to develop fatigue cracks, rather than wait for the cracks and assume the risk of a short time to propagate crack length to critical size.

Relative to erosion damage, another EPRI Supplemental Project was introduced in January 2006 and is described in EPRI document 1013086. The goal of the project is to determine qualitatively whether a hydrophobic coating applied to the stationary blades upstream of the L-0 rotor blade will alter the moisture transport characteristics and result in less water droplet damage. The liquid film on the stationary blades is the primary cause of the water damage, and if the hydrophobic coating reduces the amount of water in the film, the level of damage would be expected to be reduced as well.

GEK 46354C

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III. INSPECTION OF LAST STAGE BUCKETS THRU MANHOLE (CONDENSING TURBINES)

A turbine is occasionally shut-down for short durations due to other plant problems. At that time, an inspection of the last stage exhaust region can be made with little difficulty through the access manholes. This method of inspection can reveal a number of operational problems, last stage difficulties, or problems related to the internal condition in the machine upstream of the last stage. The following can all be detected by means of last stage inspection:

1. *Excessive Last Stage Erosion* - Excess erosion on the trailing or leading edge of the last stage buckets can be caused by mis-operation or mis-direction of water sprays, running for extended periods with a lower-than-normal reheat temperature, or because of water induction into the steam path from an extraction connection upstream of the last stage.

2. *Water Induction* - Serious mechanical damage to the latter stages may result from water induction. Visual inspection of the last stage may reveal if such a problem exists in the unit.

3. *Stress Corrosion Cracking* - The high chrome steel used for turbine buckets and dovetails is susceptible to a phenomenon known as stress corrosion cracking - which is intergranular cracking of a highly stressed part in the presence of a corrosive agent. The most common corrosive agents are caustic, chlorides, and sulfides which can be introduced into the steam path by carryover in steam, or as a residue left from a cleaning agent. Another factor required for such cracking is a warm, moist atmosphere, which is exactly the condition found in the latter stages of a steam turbine. Cracking from this cause may be found in the covers, tie-wires, erosion shield, or vane.

4. *Mechanical Failure* - Mechanical failures of vanes, covers, or tie-wires would be discovered during inspection.

5. *Foreign Material Damage* - There have been a number of instances when foreign material has been left in the unit during installation or a maintenance outage. Such material, as it becomes dislodged, may pass through the steam path and result in damage to the last stage as well as the partitions and buckets upstream.

A. INSPECTION

Considering the value of the information which can be obtained by such an inspection, the ease with which it can be obtained, and the severe consequences that may result from failure of last stage and other low pressure parts, it is recommended that the last stage buckets of all units be inspected at the customer's convenience on an annual basis. This inspection would consist of a thorough visual inspection of parts visible from inside the exhaust hood plus a red-dye inspection of certain areas of the last stage buckets. The following areas should be inspected:

1. *Tie-Wires* - Brazed or welded tie-wires should be visually inspected for cracks in the tie wire, the fillet between tie wire and vane, or in the vane adjacent to the tie wire. Loose tie wires should be inspected for evidence of tie wire cracks. Fretting or other damage in the area of the tie wire hole should also be looked for.

2. *Loose Tie Wire Sleeves* - Some buckets utilize tie wire sleeves held on by bosses. These should be visually inspected for cracks, for missing sleeves, and for sleeves which may be cocked between adjacent buckets.

3. *Erosion Shields* - Erosion shields should be visually and red-dye inspected to uncover evidence of cracking. Visual inspection can also reveal cases of severe erosion or failure of brazed joints.

4. *Bucket Vane* - The vane should be visually inspected for evidence of cracking or pitting, as well as trailing edge erosion.

5. *Peened Covers* - The covers should be inspected for indication of lifting or severe erosion of the covers or tenons. In addition, any missing covers can be discovered.

6. *Inserted Covers* - Several longer buckets employ an inserted cover. Such covers should be inspected for erosion, cracks in the tenon, or cocking of the cover between adjacent buckets. Missing covers would also be detected.

7. *Dovetail* - The accessible area of the bucket dovetail should be inspected for any sign of distress, pitting of the wheel or dovetail pins, or loose pins.

8. *Spill Strips* - The radial spill strips should be inspected for severe rubbing. In the case of a honeycomb spill strip, missing filler material would be discovered.

9. *Mechanical Damage* - All accessible rotating and stationary parts should be inspected for evidence of mechanical (impact) damage.

Problems in any of the areas described above can possibly lead to future last stage failure, with the possibility of a forced outage. In addition, they may also be symptomatic of other troubles upstream in the machine.

IV. INSPECTION USING BORESCOPE

In cases where there is a suspicion of internal damage or a build-up of deposits, selected parts may be examined during a short shutdown by means of a borescope. This may be done without opening the machine by insertion through a drain flange or a specially provided inspection opening.

V. MAJOR UNIT INSPECTION

Naturally, during a major turbine inspection with all the rotors exposed, a more thorough inspection should be made. Two methods of inspection are available; visual and nondestructive testing. A good visual examination will quite often reveal the majority of problems that might be encountered, and will generally reveal areas that should be more thoroughly examined by nondestructive testing. Visual examination early in the outage helps recognize priorities for testing and acquiring replacement materials, and can do much to assure completion of necessary action within the planned outage time span.

A. VISUAL EXAMINATION

1. *Rubbing* - Rubbing can occur both radially and axially. Look for rubbing on the covers, packings, wheels and dovetails. Significant rubbing in any of these areas can be critical because of the effect of localized heating. Cover and bucket material, especially in the high temperature stages, is subject to cracking when severely rubbed. On the wheels and rotors, the heat-affected zone may be more significant than the amount of metal removed by rubbing.

2. Erosion

   a. *Water Erosion* - Excessive water erosion can be caused by misoperation or misdirection of watersprays, running for extended periods with lower than normal reheat temperature, or because of water induction into the steam path from an extraction connection.

b. *Foreign Particle Erosion* - Excessive foreign particle erosion usually is noted on the governing stage or first stage of the reheat section. The source of particles is an oxide carryover from the boiler and steam pipes or shot peen material left in the steam leads after welding.Photographs and/or casts (R.T.V. rubber, dental compound) can be an invaluable tool for comparison at a future outage.

3. *Cracks* - Close scrutiny can also reveal cracks in covers, vanes, dovetails, or rotors. These cracks can be the results of rubbing, impact damage, fatigue, thermal stresses, or stress corrosion. Early discovery, visually, can lead to proper nondestructive testing and analysis to determine the cause and recommendations for correction.

4. *Stress Corrosion* - The materials and stress levels necessary to build the efficient units required today make various components subject to stress corrosion cracking if caustic, sulfides or chlorides are introduced into the unit. Erosion shields, dovetail pins, buckets, wheels, rotors and shafts are all subject to stress corrosion cracking.

   To minimize the possibilities of stress corrosion cracking, proper procedures must be followed when cleaning main steam piping to avoid introducing chemical contaminants into the turbine. The recommended procedures are covered in a separate instruction book article.

   Chemical cleaning of the steam side of the condenser without blanking off the low pressure elements of the turbine should never be undertaken. All low pressure turbine elements must be blocked off when chemical cleaning is being performed. There is concern that stress corrosion cracking will result from fumes of chemicals of unknown composition and their possible concentration when entering the turbine steam path. All internal areas can be affected, but of particular concern are those areas which are not open and are difficult to wash out. Such a condition exists when the fumes condense and run down into the finger-type bucket dovetails and other fit areas.

   When such a cleaning program is contemplated, specific arrangements should be made to blank-off the area at the joint between the condenser and the exhaust hood, or some other suitable block joint, with plastic sheet or canvas. The large risks of damage to the turbine from leaving the opening unblanked justify the relatively small cost required to install an effective barrier.

   During operation, chemicals in the boiler may also be carried over by entrainment or in the vapor phase to deposit in specific temperature and pressure regions of the turbine. Even low proportional carryover into the turbine, because of the concentrating mechanism which exists in the machine, can lead to damaging concentrations of contaminants. Both caustic and chlorides can be carried over in the vapor phase. In plants where demineralizers are employed, if resins become depleted or regeneration is carried out incorrectly, it is possible for sodium ions or chloride ions to be introduced into the feedwater. Thus, close attention is required in this area.

   Other sources for contamination include condenser leaks, use of less than distillate quality water for steam attemperation, and leaks in steam lines used for process heating.

5. *Deposits* - Deposits that have built up on the steam path, restricting flow and reducing the efficiency, should be removed. It is advisable that samples of deposits be taken from the steam path and rotor for laboratory analysis. This analysis can indicate whether contaminants are entering the unit, the possible source of contamination, and result in a recommendation to eliminate, or at least reduce the source of contamination; such as a change in feedwater treatment.

6. *Removal of Deposits* - Removal of insoluble deposits from rotors and buckets by blast cleaning has come to be an accepted practice. Tests indicate that the use of 220 mesh aluminum oxide, obtainable from grinding wheel or abrasive manufacturers, is satisfactory. It produces a soft gray satin finish and slightly increases the fatigue strength of the material. In addition to the relatively pure nature of the product, it also contains a corrosion inhibitor.

   Some of the materials that have been tested in our Laboratory were found to be inert composition, while in other samples, traces of sodium chloride (NaCl), which is highly detrimental to 12-chrome alloys, were found. Furthermore, our tests have indicated that sand and fly-ash blasting result in a lower fatigue strength.

   While inherent sturdiness of General Electric turbine buckets has been long recognized, carelessness in cleaning operations may seriously affect the mechanical strength of the part. Hand cleaning with files, scrapers, etc. often produces heavy transverse scratches which can cause greatly reduced fatigue strength in turbine buckets.

   Blast cleaning in general is far superior to hand cleaning methods and results in a much quicker, less expensive, and superior job. It reaches fillets and crevices that cannot be reached by hand cleaning methods.

   Blast cleaning should be done after a complete visual inspection and prior to any nondestructive testing.

   Good experience has been obtained on industrial size turbines with a water washing procedure to remove water soluble deposits such as caustic. A combination of steam cleaning, followed by soaking in a pure water or a water and cleaner mixture is used to leach deposits from the dovetails. Normally blast cleaning of the rotor is required after the cleaning operation to prepare the exterior rotor surface for magnetic particle inspection. This procedure should be applied with caution since, without removal of the buckets, it is impossible to determine for sure if all deposits have been removed from the interior dovetail surfaces. Although the procedure has been used by owners to remove water soluble contaminants, General Electric cannot be held responsible for the results or subsequent consequences of this procedure. More specific information on the water washing procedure will be made available by General Electric upon request.

   It is important to emphasize that under circumstances of severe contamination with corrosive deposits such as caustic, additional actions are generally required to assess if stress corrosion cracks have initiated, especially in more highly stressed regions such as dovetails. Ultrasonic examinations can be used effectively in many cases to inspect internal regions without disassembly. However, removal of partial or full rows of buckets may be required in cases where the potential for cracking is particularly high, or where ultrasonic inspections cannot be used effectively because of the geometry. For built-up rotors, disassembly of wheels may be required in some cases to inspect wheel bore and keyway surfaces.

B. NONDESTRUCTIVE TESTING

There are several means available to test the soundness of the turbine rotor and buckets; X-ray, ultrasonic test, magnetic particle test, and red-dye penetrant test or Zyglo-test. Each of these tests has its limitations and is more applicable to certain areas.

1. *X-Ray* - X-ray testing is most applicable during manufacture of buckets and has not had widespread usage as an inspection tool for an in service unit, primarily because the defects being tested for are not internal to the part. However, X-ray testing can be used to check the erosion shields on last stage buckets.

2. *Ultrasonic Testing* - The use of ultrasonic testing is becoming more widespread. Areas that can be inspected by ultrasonic means are: bucket dovetail pins, bucket and rotor dovetails, integral rotor bodies, and shrunk-on wheels. Special tests have been developed by General Electric to detect cracked dovetail pins, cracked bucket dovetails and wheel dovetails, and to determine the depth of a crack in a rotor surface.

   Ultrasonic testing is also now available as a test which should be routinely applied to integral (no shrunk-on wheels) rotors. Special test recommendations regarding critical rotors are normally issued by letter or T.I.L. But, in addition, we recommend that all integral rotors have an inspection conducted after about 10 years of service. Reinspection intervals after the first test will be specified and will usually be in the range of 3-10 years. The details of the inspection depend upon whether the rotor has a bore. On boreless rotors, an ultrasonic inspection is performed from the rotor peripheral surfaces. The extent of coverage is limited by the external geometry of the rotor. A more detailed examination is possible on rotors with a bore. In these cases, the inspection would also include a visual and magnetic particle inspection of the bore surface and an ultrasonic inspection from the rotor bore. Inspection recommendations for nuclear units with 1500 and 1800 RPM rotation speed differ slightly, and are described in GEK 72178.

   It is recommended that General Electric personnel, especially trained, be utilized for these tests.

3. *Magnetic Particle Testing* - Magnetic particle testing has long been established as a reliable and quick means of testing the entire assembled rotor; however, care must be exercised in testing the high temperature stages. The high strength materials can be magnetic particle tested though it is a little more difficult and time consuming than on the more readily magnetized materials used in the lower temperature regions.

   CAUTION

   Erosion shields are of non-magnetic materials and must be tested by a dye-penetrant or fluorescent penetrant.

4. *Red-Dye Penetrant or Zyglo* - Red-dye penetrant or Zyglo must be utilized in testing non-magnetic materials such as those used in erosion shields. It is also useful in verifying magnetic particle test results. Trained personnel should be used for this test due to the possibilities of mis-interpretation of results.

The turbine rotors and blading are highly stressed components, utilizing high strength alloys. Proper application and utilization of monitoring equipment and inspection procedures can do much to increase the reliable, efficient life of the turbine-generator unit.

Properly applied and interpreted nondestructive testing also can do much to eliminate the possibility of a future forced outage.

The above discussion, by necessity, is not intended to be a detailed instruction for inspections. The local General Electric District Office can supply technical direction and trained personnel to make a complete and thorough inspection. The General Electric Company will provide repair and operating recommendations upon reporting of the results of any inspection. Upon receipt of a complete description of the problem, General Electric engineers will describe the repair options available, considering the design parameters on the stage, service experience with other similar designs, and experience obtained with various kinds of repair procedures.

Rev. C (8/90)

GE Power Systems

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IP7019407

General Electric Power Systems

Technical Information Letters

630-4: PERIODIC INSPECTION OF LAST STAGE BUCKETS

March 26, 1972

There are a number of well known procedures which a utility can follow to monitor the condition of its turbine-generators. It is recognized, for example, that monitoring turbine-generator vibration level is a means for detecting problems in the turbine rotating parts. This is because any circumferential variation in weight in the rotating parts will result in an unbalance which will change the unit's vibration at its bearings. In addition, the thermodynamic performance of a unit frequently gives an indication of the internal condition of a machine. An increase in stage pressure may indicate a buildup of deposits or internal mechanical damage. Likewise, changes in turbine section efficiency or unit capability also can signify deposits or internal damage.

It is recommended that the periodic inspection of LSB's be included with the other established methods of monitoring turbine conditions and the inspection can be accomplished without disassembly of the unit by entering the exhaust hood through the manholes.

An inspection of the last stage area can reveal a number of operational problems, last stage difficulties, or problems related to the internal condition in the machine upstream of the last stage. The following can all be detected by means of last stage inspection.

1. **EXCESSIVE LAST STAGE EROSION**

   Excess erosion on the trailing or leading edge of the last stage bucket can be caused by misoperation or misdirection of water sprays, running for extended periods with a lower than normal reheat temperature, or because of water induction into the steam path from an extraction connection upstream of the last stage.

2. **WATER INDUCTION**

   Serious mechanical damage to the latter stages may result from water induction. Visual inspection of the last stage may reveal if such a problem exists in the unit.

3. **STRESS CORROSION CRACKING**

   The high chrome steel used for turbine buckets and dovetails is susceptible to a phenomenon known as stress corrosion cracking - which is inter-granular material cracking of a highly stressed part in the presence of a corrosive agent. The most common corrosive agents are chlorides and sulphides which can be introduced into the steam path by carryover in steam, or as a residue left from a cleaning agent. Another factor required for such cracking is a warm, moist atmosphere, which is exactly the condition found in the last stages of a steam turbine. Cracking from this cause may be found in the covers, tie-wires, erosion shield or vane.

4. **MECHANICAL FAILURE**

   Mechanical failures of vane, covers, or tie-wires would be discovered during inspection.

5. **FOREIGN MATERIAL DAMAGE**

   There have been a number of instances when foreign material has been left in the unit during an installation or maintenance outage. Such material, as it becomes dislodged may pass through the steam path and result in damage to the last stage as well as the partitions and buckets upstream.

INSPECTION

Considering the value of the information which can be obtained by such an inspection, the ease with which it can be obtained, and the severe consequences that may result from failure of last stage and other low pressure parts, we recommend that the last stage buckets of all units be inspected at the customer's convenience on an annual basis. This inspection would consist of a thorough visual inspection of parts visible from the exhaust hood plus a red-dye inspection of certain areas of the last stage buckets. The following areas should be inspected:

1. **TIE-WIRES**

   Brazed or welded tie-wires should be visually inspected for cracks in the tie-wire, the fillet between tie-wire and vane, or in the vane adjacent to the tie-wire. Loose tie-wires should be inspected for evidence of tie-wire cracks. Fretting, or other damage in the area of the tie-wire hole, should also be looked for.

2. **LOOSE TIE-WIRE SLEEVES**

   Some 3600 RPM buckets utilize tie-wire sleeves held on bosses. These should be visually inspected for slits or tears, for missing sleeves, and for sleeves which may be cocked between adjacent buckets.

3. **EROSION SHIELDS**

   Erosion shields should be visually and red-dye inspected to uncover evidence of cracking. Visual inspection can also reveal cases of severe erosion or failure of brazed joints.

4. **BUCKET VANE**

   The vane should be visually inspected for evidence of cracking or pitting, as well as trailing edge erosion.

5. **PEENED COVERS**

The cover should be inspected for indication of lifting or severe erosion of the cover or tenons. In addition, any missing covers can be discovered.

6. **INSERTED COVERS**

Several longer 3600 RPM buckets employ an inserted cover. Such covers should be inspected for erosion, cracks in the tenon, or cocking of the cover between adjacent buckets. Missing covers would also be detected.

7. **DOVETAIL**

The accessible area of the bucket dovetail should be inspected for any sign of distress, pitting of the wheel or dovetail pins or loose pins.

8. **SPILL STRIPS**

The radial spill strips should be inspected for severe rubbing. In the case of a honeycomb spill strip, missing filler material would be discovered.

9. **MECHANICAL DAMAGE**

All accessible rotating and stationary parts should be inspected for evidence of mechanical (impact) damage. Problems in any of the areas described above can possibly lead to future last stage failure, with the possibility of a forced outage. In addition, they may also be symptomatic of other troubles upstream in the machine. The General Electric Company will provide repair and operating recommendations upon reporting of the results of the inspection. Upon receipt of a complete description of the problem, General Electric engineers will describe the repair options available, considering the design parameters on the stage, service experience with other similar designs, and experience obtained with various kinds of repair procedures.

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